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Original Research Article

Growth and Yield Assessment of Crops Cultivated in Ex-situ Conditions of Lichenized and Non-lichenized Soils in Kumaun Himalaya

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Abstract: Agriculture is one of the major economic sources in remote areas of Uttarakhand. People in this region depend on tree litter for their agricultural manure. In these areas, lichen litter can also be used along with other litter for improving growth, yield and quality of the traditional crops. In the present investigation two important food crops were cultivated in lichenized and non-lichenized soil under ex-situ condition. For this purpose lichenized soil which contains lichen taxa *Usnea*, *Parmotrema* and *Everniastrum* and non-lichenized soil (no lichen mixed soil) were taken. Observations on growth of different parts of plant and yield of wheat and rice crop were taken on the fortnightly interval basis. Total ten observations on wheat crop and eight on rice crop were taken during their existing cropping seasons. In these observations- seed germination rate, stem height, leaf area, number of inflorescence, yield and seed quality of both the cereals grown in lichenized and non-lichenized soil were taken. Wheat crop indicates higher seed germination percentage ranged between 13.2% with *Parmotrema* decomposed soil to 66.8 with *Usnea* mixed soil within a period of 45 days of seed sowing. A maximum yield of wheat ranged between 168.4 to 250.0 g/m^2 was estimated in lichenized soil. Less yield of wheat was found in non-lichenized soil i.e. 163.1 g/m^2. The study concludes that in high altitude areas where lichen occurs luxuriantly, their litter can be employed as agricultural manure with litter of higher plants. Lichen litter also improves soil nutrients.

Key words: Agricultural crops, lichenized and non-lichenized soil, lichen taxa, observations, temperate region.

Introduction

Uttarakhand formed on 9th November, 2000 is the 27th state of India. It has been separated from Uttar Pradesh. As per the geographical status of the state, most of the area comes under mountainous zone. In these mountainous areas basic facilities for surviving are still limited. There are no industries, factories, multinational companies, malls, institutions etc. which can employ people for their income. Therefore, people have only agriculture sector as a major source of their income. There are two divisions of Uttarakhand i.e. Kumaun Himalaya and Garhwal Himalaya. Out of the total thirteen districts of Uttarakhand, maximum nine districts namely Almora, Pithoragarh, Bageshwar and Champawat of Kumaun region and Rudraprayag, Chamoli, Uttarakashi, Pauri and Tehri districts of Garhwal are purely hilly areas. Some parts of Dehradun and Nainital districts are also situated in hilly areas. Only two districts i.e. Udham Singh Nagar and Haridwar are purely in plain region.

Kumaun Himalaya lies between latitude 28°44'-30°49' N and longitude 78°45'-81°5' E. The temperate to alpine areas of Kumaun Himalaya are well known for its natural resources because of varied altitude, topography, climate, soil and vegetation. This region is most attractive from natural as well as floristic view point among all the regions of the area. It provides many dimensions for its exploration. In the temperate regions of Kumaun Himalaya lichen grows abundantly on oak trees. Lichens are basically non-vascular cryptogams, thalloid, branched and slow growing plants. Lichen thallus is composed of two distinct organisms, a fungus (mycobiont) and an alga (phycobiont), forming a self supporting combination. A famous lichenologist Trevor Goward says that "lichens are fungi that have discovered agriculture" (Dayan and Romagni, 2001). It means lichens are those common pioneer species which make a previously barren area suitable for other plants and organisms to grow. On the basis of thallus structure lichens are foliose, fruticose and crustose type. The foliose and fruticose forms are known as macrolichens which are abundantly found in high altitude areas in the Himalaya. Lichens are used as spices, perfumery and medicines by the mankind and as fodder by musk deer and Piccas in high altitude regions (McCune and Geiser, 1997). Beside these plants are also ecologically very important. They fix atmospheric nitrogen and play a great role in the forest nutrient cycling (Pike, 1978; Maser, *et al.,* 1985). The macrolichen species viz. foliose and fruticose are collected by the local communities residing in temperate areas of Uttarakhand (Negi, H.R., 2000; Upreti, *et al.,* 2002). In these areas lichen litter along with tree litter is collected by the villagers for manuring purpose. Thus these lichen species directly decompose in their agricultural land. They improve the soil capacity by increasing the soil macronutrients which are essential for better growth and production of our food crops (Arya, *et al.,* 2017). Therefore, the present study is focused on the growth and yield of two important food crops which are cultivated in lichenized soil and also in lichen free (non-lichenized) soil.

Materials and methods

Soil sample collection and soil nutrient test

Soil samples were collected as per method used by Carter and Gregorich (2006). A 'V' shaped cut to a depth of 15 cm was made using spade at 15 spots in the agricultural field located at 1755 m altitude which lies between latitude 29° 23.053¹ N and longitude 79° 38.663¹ E at Mukhteshwar (Nainital) for soil collection. The collected soil was mixed and brought to the laboratory. This soil was put in the sample pots for further experiment.

Chemical analysis of the soil was done at Uttarakhand Government Soil Testing Laboratory, Bhimtal (Nainital). The chemical nutrients of both lichenized and non-lichenized soil has already been analyzed during previous study by Arya, *et al.* (2017). This soil containing the identified nutrients was taken for the current study.

Ex-situ experiment

An ex-situ experiment was performed in the botanical garden of Botany Department, S. S. J. Campus Almora (Uttarakhand). First of all 40 sample pots of equal size were taken for lichen decomposition activity. These pots were grouped in two sets of 15+5 (lichenized soil + non-lichen soil or control) each for wheat and rice cultivation respectively. All the sample pots were filled with tested agricultural soil. Out of these, five sample pots each were used for the selected three lichen taxa *Usnea* (Fig. 1A), *Everniastrum* (Fig. 1B), *Parmotrema* (Fig. 1C) and the remaining five pots were used for non-lichenized soil (Fig. 1). The same number of replicates was applied for the second set of pots. These experimental pots were filled with soil weighted 10kg each. The upper layer of each pot was covered fully with the selected macrolichens

Fig. 1. Lichen taxa used for decomposition: A- *Usnea*, B- *Everniastrum*, C- *Parmotrema* and D- Lichenized soil.

weighted 11.2 gm. Such quantity of lichen was found sufficient for their decomposition. A fixed amount of about 11.2 gm lichen mass was mixed with the soil samples in each of the fifteen pots of the three selected lichen genera (Fig. 1). It is because the thallus structure of these macrolichens (foliose and fruticose forms) is bigger in size and their availability in the study area is limited. Also only fresh harvested lichens were taken for decomposition activity (Fig. 1). The lichen mass, mixed in each of these 15 pots was estimated with the help of electronic weighing machine. This soil-lichen mixture was left to decompose for six months (Fig. 1D). Observations on lichen mass loss were taken. After this, both lichenized and non-lichenized soils were further used to assess their impact on the growth and development of the important food crops of the area (Fig. 2). During Rabi season from 25 November 2015 to 23 April 2016, on the first day equal number of seeds of wheat was sown in each pot of the first set of pots. In the second phase during Kharif season from 20 June 2016 to 18 October 2016 rice (paddy) seeds sown in another set. In both the cases observations were taken at fortnightly intervals.

Observations and calculation

During the fortnightly observations various crop growth parameters such as seed germination, stem height, leaf area increment, number of produced leaves, spikes, seeds and cereal were observed and analyzed. Cereal yield (g/m^2) was measured using electronic weighing machine.

Data analysis

Statistical analysis was performed using SPSS version 16. The response of lichenized and non-lichenized soil on various characteristics of wheat and rice crops was examined by calculating:

$$\text{Seed germination rate (\%)} = \frac{\text{Number of total sprouted seeds in a pot}}{\text{Total no.of seed shown}} \times 100$$

$$\text{Average stem height (cm)} = \frac{\text{Lenght of all sampled seedlings or plants of a pot}}{\text{No.of sampled seedlings or plants of a pot}}$$

$$\text{Average leaf area (cm}^2\text{)} = \frac{\text{Total lenght X width of all sampled leaves of a pot}}{\text{Total no.of leaves sampled from a pot}}$$

$$\text{No.of leaf per plant} = \frac{\text{Total no.of leaves of all sampled seedlings or plants}}{\text{Total no.of seedlings or plants sampled}}$$

$$\text{No.of spikes per plant} = \frac{\text{Total no.of spikes found on all sampled plants}}{\text{Total no.of plants sampled}}$$

$$\text{No.of seeds produced per spike} = \frac{\text{Total no.of seeds on all sampled spikes}}{\text{Total no.of spikes sampled}}$$

$$\text{No.of seeds produced per pot} = \frac{\text{Total no.of seeds produced in all pots}}{\text{Total no.of pot studied}}$$

$$\text{Net yield (g/m}^2\text{)} = \frac{\text{Total weight of seeds produced in all pots}}{\text{Total no.of pots studied}}$$

Sensitivity Index (SI) was determined by following the method of Abdul and Anderson (1973). Similarly the Response Index (RI) was calculated as per the method given by Williamson and Richardson (1988). The magnitude of inhibition versus stimulation by lichen impact on seed germination and stem height (length) was calculated by using following formula.

$$\text{Sensitivity Index (SI)} = \frac{\text{Germination percentage in nonichenized soil}}{\text{Germination percentage in lichenized soil}}$$

The Response Index (RI)

(i) When germination of crops cultivated in lichenized soil (T) is lower than the control (C) i.e. non-lichenized soil

RI= (T/C)-1

(ii) When germination of crops cultivated in lichenized soil (T) is higher than the control (C) i.e. non-lichenized soil

RI= 1-(T/C)

[If RI> 0 treatment (T) stimulated germination; if RI= 0 no effect; if RI< 0 treatment (T) inhibited germination]

Nutritional value assessment test

The test for nutritional values of crop yield was performed at Vivekanand Pravateeya Krishi Anusandhan Sansthan, Hawalbag (Almora) with their technical staff (Fig. 3. A-B). This test was performed to observe the value of protein, carbohydrate and fat of wheat and rice cultivated in lichenized and non-lichenized soil. The protein substance was estimated by Bradford method (Bradford, 1976). Total carbohydrate

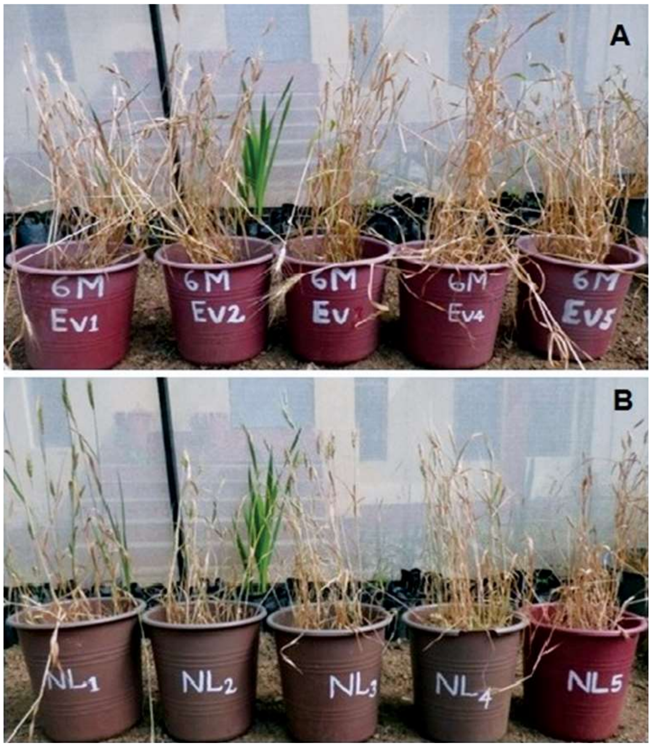

Fig. 2. A-B. Crop grown in A: lichenized soil, B: non-lichenized soil.

Fig. 3. A-B. Laboratory activities for testing nutritional values.

value was determined spectrophotometrically by anthrone method (Hedge and Hofreiter, 1962). Gravimetric method was used for determination of total fat content as described by Bligh and Dyer (1959).

Results

The wheat crop became matured on 10th observation i.e. 150th day of the experiment. Similarly, the rice crop was prepared in 120 days of its cultivation period. Total eight parameters viz. seed germination rate, stem height, leaf area, number of leaves, number of seeds per spikes and per pot, total yield and nutritional value were estimated for each crop. Better growth and yield of both the crops was found highest in lichenized soil and lowest in non-lichenized soil. *Usnea* and *Parmotrema* decomposed soil supported to all the eight growth forms. However, lichen taxa *Everniastrum* mixed soil supports to the lowest growth. Analysis of variance showed that leaf area increment, number of seeds and seed yield quantity of both the crops cultivated in the lichen decomposed soil were influenced significantly. Seed germination rate and production of number of spikes (inflorescence) also showed significant effect of lichenized soil on rice crop. However, impact of lichens on seed germination rate, number of seedlings of wheat and stem height increment and number of leaves of rice emerged was found insignificant (Table 1). During the study following growth and development in different stages of both the crops cultivated in lichenized and non-lichenized soils were analyzed and discussed:

1. Effect of lichen taxa on seed germination

Total three fortnightly observations were taken to analyze the seed germination rates. Here wheat crop indicated higher seed germination rate ranged between 13.2 ± (SD); 7.44% in *Parmotrema* mixed soil to 66.8 ± 10.4% in soil mixed with *Usnea* within a period of 45 days of seed sowing (Table 2; Fig. 4A). Lower germination rate of wheat was recorded in non-lichenized soil and it was ranged between 9.2 ± 3.70% to 56.4 ± 10.5% (Table 2; Fig. 4A). After this in the second observation on 30th day wheat sowing *Usnea* decomposed soil

Table 1. Analysis of variance (ANOVA) for investigated traits in response to food crops.

Parameters	Df	SGR	SH	LA	NLs	NSs	NSds	NSY	CY
Wheat crop	4	0.756ns	4.249s	6.367s	14.888s	0.756ns	5.478s	5.246s	5.246s
Rice crop	4	4.909s	1.604ns	3.341s	65535ns*	55.815s	31.356s	64.039s	64.039s

s: significant at 5%, ns: not significant, Df: degree of freedom, SGR: Seed germination rate (%), SH: Stem height (cm), LA: Leaf area (cm2), NLs: Number of leaves/plant, NSds: Number of seeds yield/spike, NSs: Number of spikes/m2 area, NSY: No. of seeds yield/ m2 area, CY: Yield quantity (g/m2). *equal number of leaves were found on each sampled plant or stem.

Table 2. Development in wheat crop on different growth stages.

Growth stages and yield	Lichen decomposed soil			Non-lichenized soil (Control)
	Usnea	Parmotrema	Everniastrum	
Seed germination (%)	66.8 ± 10.4	61.6 ± 10.9	60.8 ± 8.4	56.4 ± 10.5
Stem height (cm)	33.4 ± 4.2	24.8 ± 2.0	33.0 ± 5.1	32.8 ± 0.6
Leaf area (cm2)	22.6 ± 2.2	21.1 ± 0.6	22.8 ± 2.5	25.7 ± 0.9
No. of leaves/ plant	6.0 ± 0.1	5.6 ± 0.9	5.0 ± 0.1	5.0 ± 0.2
No. of spikes/ m2 area	611 ± 150	590 ± 108	537 ± 118	490 ± 118
No. of seeds yield/ spike	11.4 ± 0.8	08.8 ± 1.0	14.8 ± 2.9	10.4 ± 2.4
No. of seeds yield/ m2 area	6770 ± 1182	5148 ± 945	7664 ± 1079	4975 ± 1287
Cereal yield (g/m2 area)	221.0 ± 39.4	168.4 ± 31.5	250.0 ± 34.2	163.1 ± 42.1

*±: Standard Deviation (SD)

also maintained higher value of germination rate of wheat i.e. about 60.4 ± 13.29%. However, soil mixed with lichen taxa *Parmotrema* and *Everniastrum* represented equal germination rates of about 55.2 ± 13.44% and 55.2 ± 10.70% respectively in the second observation. But in the third or final observation on 45th day after sowing, germination rate was again increased and risen up to maximum 66.8 ± 10.4% in *Usnea* and 61.6 ± 10.98% and 60.8 ± 8.4% in soil having *Parmotrema* and *Everniastrum* respectively (Table 2; Fig. 4A).

Whereas in the non-lichenized soil, seed germination rate was found slow and reached up to 56.4 ± 10.53% only. It was observed that lichenized soil supported to more than 60% germination of wheat seeds and non-lichenized soil represented less germination. After 45 days of sowing, no germination of wheat seeds occurred in both the soil conditions. Hence these germination rates were assumed fixed up to 150 days or on the day of crop harvesting for entire season of the wheat crop (Table 2; 4A).

In case of germination of rice seeds, more than 80% germination was recorded in the lichenized soil. Only two fortnightly observations on rice seed germination were taken. In the first observation on 15th day of sowing, maximum germination rate was measured about 84.4 ± 4.48% in *Usnea* decomposed soil followed by 82 ± 4.38% in *Parmotrema* and 76 ± 6.69% in *Everniastrum* mixed soil. In the second observation i.e. on 30th day of sowing, seed germination rate was measured highest in *Parmotrema* decomposed soil represented by 85.2 ± 5.3% followed by 85.2 ± 4.1% in *Usnea* and 79.6 ± 5.12% in *Everniastrum*. Like wheat, lower germination rate of rice seeds was also recorded in non-lichenized soil i.e. 72 ± 7.5%. In both the soil highest germination rate of rice seeds was considered as a final germination rate up to the day of crop harvesting i.e. 120th day of seed sowing (Table 3; Fig. 4A). Sensitivity Index (SI) was found increased with different lichen taxa indicating that germination was more influenced by decaying lichen material in the soil (Table 4). Lichenized soil containing lichen taxa *Everniastrum* showed highest SI (0.92) followed by *Parmotrema* mixed soil (0.91) for wheat seedlings and *Usnea* decomposed soil (0.84) for both wheat and rice crop.

The Response Index (RI) values were negative in crops cultivated in soils having different lichen taxa except for

Table 4. Sensitivity Index in terms of germination percentage as affected by lichens.

Lichenized soil	Sensitivity Index (SI)	
	Wheat	Rice
Usnea	0.84	0.84
Parmotrema	0.91	0.84
Everniastrum	0.92	0.90

Table 5. Response Index for seed germination and stem height of crops grown in lichenized soil.

Lichenized soil	Seed germination		Total stem height	
	Wheat	Rice	Wheat	Rice
Usnea	-0.16	-0.16	-0.02	-0.16
Parmotrema	-0.09	-0.16	-0.24	-0.2
Everniastrum	-0.08	-0.1	1.00	-0.5

wheat stem height which showed stimulated value (Table 5). These results indicate that most of the investigated parameters were inhibited due to impact of lichen thalli.

Table 6. Nutritional value analysis (mg /100 mg).

Crop	Soil condition	Protein	Carbohydrate	Fat
Wheat	*Usnea* decomposed soil	4.75	25.31	2.73
	Everniastrum decomposed soil	4.42	23.04	2.57
	Parmotrema decomposed soil	6.50	22.21	1.00
	Non-lichenized soil	6.54	25.42	0.88
Rice	*Usnea* decomposed soil	0.24	15.95	0.43
	Everniastrum decomposed soil	-	-	-
	Parmotrema decomposed soil	0.28	18.28	0.22
	Non-lichenized soil	-	-	-

2. Stem growth and increment

The stem was found erect, cylindrical and hollow at nodes. Stem height of wheat and rice was observed greater in crop which is cultivated in lichenized soil. Wheat plant cultivated in soil having *Usnea* and *Everniastrum* refers maximum stem height about 33.4 ± 4.2cm and 33.0 ± 5.1cm respectively which was followed by 24.8 ± 2.0cm in *Parmotrema* mixed soil

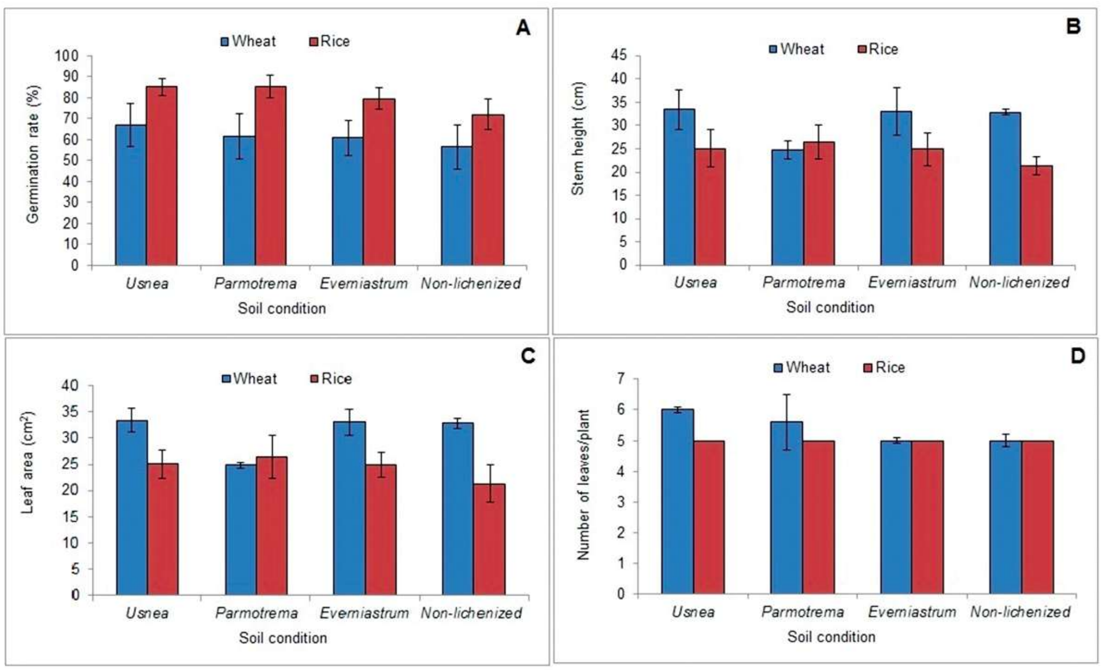

Fig. 4. Growth and increment in different parts of crop plants cultivated in lichenized and non-lichenized soils- A: Wheat crop indicating higher seed germination rate in *Usnea*, *Parmotrema* and *Everniastrum* mixed soils whereas both the crops showing lower germination rate in non-lichenized soil; B: Wheat plant cultivated in *Usnea* and *Everniastrum* mixed soil refers maximum stem height however rice plant indicated maximum height with *Parmotrema* and stem height of both the crops was recorded lower in non-lichenized soil; C: Highest leaf area increment for rice crop was calculated in lichenized soil having *Parmotrema* followed by *Everniastrum* and *Usnea* however, lowest leaf area was calculated for wheat in *Parmotrema* mixed soil; D: In wheat crop maximum number of leaves per plant was formed in *Usnea* decomposed soil followed by *Parmotrema* and *Everniastrum* whereas less leaves of both the crops were formed in non-lichenized soil.

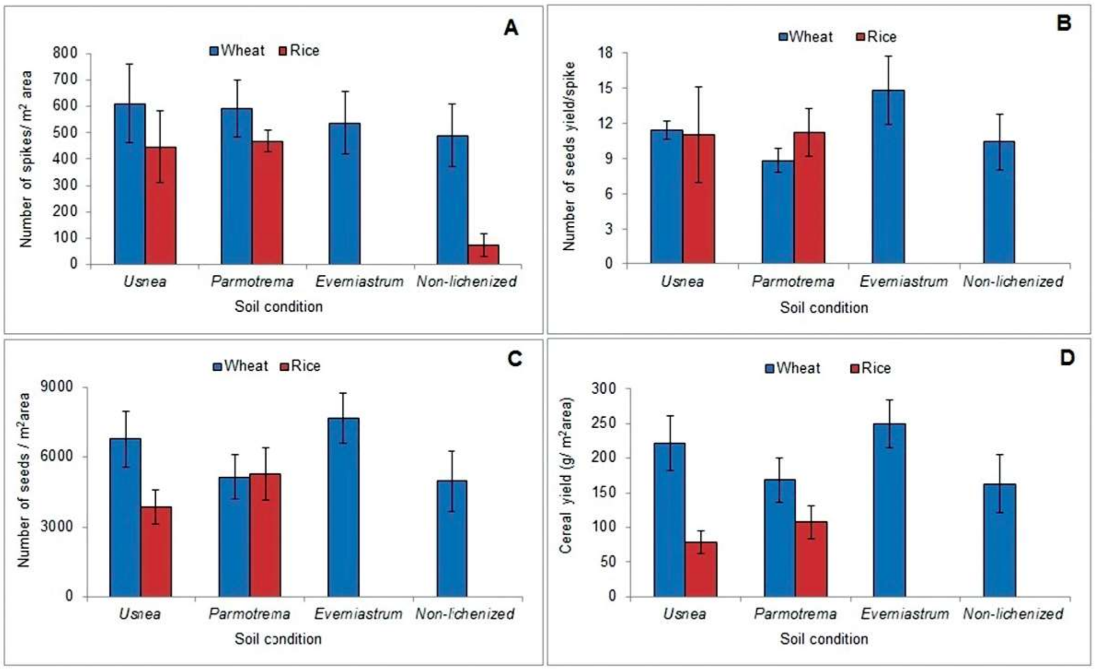

Fig. 5. Production of spikes and crop yield in lichenized and non-lichenized soil- A: Wheat crop produced maximum spikes/m^2 area cultivated in *Usnea* followed by *Parmotrema* and *Everniastrum* mixed soils whereas minimum spikes/m^2 area of rice crop was calculated with non-lichenized soil; B: Maximum wheat seeds yield/ spike were recorded with *Everniastrum* followed by *Usnea* and non-lichenized soil however rice seeds were not formed in *Everniastrum* mixed soil and non-lichenized soil; C: Seeds yield highest per m^2 were observed for wheat in *Everniastrum* decomposed soil followed *Parmotrema* and *Usnea* mixed soil; D: Highest yield (g/m^2 area) of Wheat was recorded in lichenized soil having *Everniastrum* lichen taxa followed by *Usnea* and *Parmotrema* contained soil whereas less yield of wheat was found in non-lichenized soil.

(Table 2; Fig. 4B). Stem height of rice plant in lichenized soil with *Parmotrema* showed maximum height about 26.4 ± 3.7cm followed by 25.1 ± 4.0cm in *Usnea* and 24.9 ± 3.6cm in *Parmotrema*. However, stem height of both wheat and rice plants was recorded lower in non-lichenized soil i.e. 32.8 ± 0.6cm and 21.3 ± 1.9cm respectively (Table 2 & 3; Fig. 4B). Cultivation of both the crops in lichenized soil supported better germination, stem height and other growth forms.

An increasing trend of stem height was developed on 4th observation i.e. from 60th day of sowing in both the soil types. In lichenized soil, the average stem height reached maximum up to 33.4 ± 4.2cm in 135 days. *Parmotrema* showed minimum increment in wheat stem height about 24.8 ± 2.03cm within 135 days (Table 2; Fig. 4B). In both the soil conditions no increment in stem height occurred after 135 days of sowing. This height was found constant up to the final observation on the day of crop harvesting i.e. on 150th day.

3. Leaf formation and leaf area

Leaf was not produced in 1st and 2nd observation. Leaf initiation started in 3rd observation of sowing of wheat. The alternate leaves emerged from the nodes. Therefore, number of leaves on an axis was recorded equal to the number of nodes. In wheat crop maximum number of leaves per plant (6.0 ± 0.1) was formed in *Usnea* decomposed soil followed by 5.6 ± 0.9 in *Parmotrema* and 5.0 ± 0.1 in *Everniastrum*. It was recorded approximately the same i.e. 5.0 ± 0.0 leaves/plant in case of rice crop cultivated in these three different lichenized soil (Table 2 & 3; D). On the other hand, in non-lichenized soil both the plant of wheat and rice bears five leaves per plant grown.

Out of ten observations, number of leaves and increment in leaf area was recorded in eight observations only. Increment in leaf area was recorded higher (37.4 ± 4.1 cm^2) for rice crop grown in lichenized soil with lichen taxa *Parmotrema* followed by 36.7 ± 2.4 in *Everniastrum* and 31.6

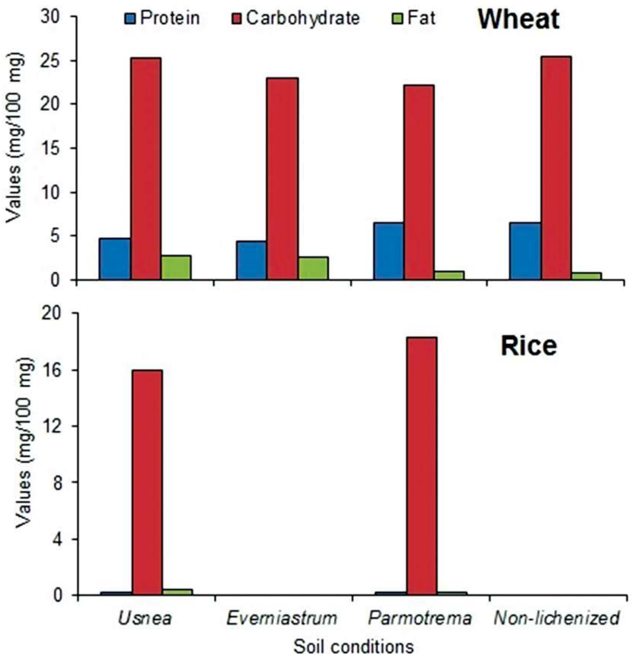

Fig. 6. Graph showing nutritional values of crops cultivated in lichenized and non-lichenized soil: In both the crops carbohydrate value was observed highest in lichenized as well as in non-lichenized soil. Both the soils support to other nutrients like protein and fat for wheat crop however less protein and fat was observed in rice cereal grown in *Usnea* and *Parmotrema* soil and no rice was produced with *Everniastrum* and non-lichenized soil.

± 2.7 in *Usnea* (Table 3; Fig. 4C). However, the leaf area was calculated lower (21.1 ± 0.6 cm^2) for wheat in the lichenized soil of *Parmotrema* (Table 2; Fig. 4C).

Production of spikes and seeds or cereal

For representing yield values the size of the experimental pots is converted into square meter (m^2) area. Therefore the production of spikes, seeds and cereal yield is calculated in per meter square land area.

4. Formation of spikes

Un-branched spikes (inflorescence) were developed directly on stem axis. Maximum spikes 611 ± 150/m^2 area were recorded for wheat crop cultivated in *Usnea* decomposed soil followed by 590 ± 108 in *Parmotrema* and 537 ± 118 in *Everniastrum* decomposed soils. In case of rice crop grown in non-lichenized soil only 74 ± 42 spikes /m^2 area were recorded (Table 2 & 3; Fig. 5A).

5. Seed or cereal yield

It was observed that the maximum yield of both the crops was found in lichenized soil. Maximum wheat seeds 14.8 ± 2.9/ spike were recorded with soil having *Everniastrum* followed by *Usnea* and non-lichenized soil about 11.4 ± 0.8 and 10.4 ± 2.4 seeds/ spike (Table 2; Fig. 5B). However, in case of rice *Parmotrema* mixed soil produced 11.2 ± 2.0 seeds/ spike followed by *Usnea* mixed soil yielding 11.0 ± 4.1 seeds/ spike. There is no seed yield in *Everniastrum* decomposed soil and non-lichenized soil (Table 3; Fig. 5B).

Highest yield of seeds were observed for wheat about 7664 ± 1079 seeds/m^2 area in *Everniastrum* decomposed soil followed by 6770 ± 1182 with *Parmotrema* and 5148 with *Usnea* mixed soil. In non-lichenized soil only 4975 ± 1287 seeds/ m^2 area were recorded (Table 2; Fig. 5C). In case of rice crop maximum 5253 ± 1121 seeds/m^2 area were produced in *Parmotrema* containing soil followed by *Usnea* soil with 3864 ± 742 seeds/m^2 area. Rice seeds were not formed in non-lichenized soil (Table 3; Fig 5C).

Wheat crop yield was found highest 250.0 ± 34.2 g/m^2 in the lichenized soil having *Everniastrum* lichen taxa. It was followed by 221.0 ± 39.4 g/m^2 wheat produced with *Usnea* decomposed soil. In lichenized soil the lowest yield of wheat was obtained from *Parmotrema* contained soil i.e. 168.4 ± 31.5 g/m^2. In non-lichenized soil less yield of wheat (163.1 ± 42.1 g/m^2) was recorded (Table 2; Fig. 5D). Only 78.9 ± 15.8 g/m^2 and 107.9 ± 23.7 g/m^2 rice was produced from lichenized soil containing *Usnea* and *Pramotrema* lichens respectively (Table 3; Fig. 5D). In non-lichenized soil rice seeds could not be formed hence there was no rice yield in this soil.

6. Nutritional value analysis

On the basis of seed quality test, nutritional value of protein and carbohydrate was recorded higher in seeds of crops cultivated in non-lichenized soil as compared to seeds grown in lichen decomposed soil. But nutritional value of fat was recorded higher in seeds grown in lichen decomposed soil. A detail account of nutritional values is given below:

i. **Protein:** Value of protein was recorded higher in wheat seeds grown in non-lichenized soil i.e. 6.54 mg/100 mg. Value of protein in seeds cultivated in lichenized soil was recorded highest 6.50 mg/100 mg in *Parmotrema* which is very close to the value in non-lichenized soil. This value of protein was found 4.75mg/100gm in *Everniastrum* and 4.42 mg/100 mg in *Usnea* decomposed soil (Table 6; Fig. 6).

   In rice seeds, poor quantity of protein was observed in *Parmotrema* and *Usnea* decomposed soil represented by 0.28 mg/100 mg and 0.24 mg/100 mg (Table 6; Fig. 6). The absence of rice seed production in non-lichenized soil indicates that the lichen decomposed soil support to better growth and development of rice crop and they produce seeds.

ii. **Carbohydrate:** Carbohydrate value was also recorded higher and approximately alike to the wheat seeds cultivated in lichen free soil and *Usnea* decomposed soil. These values are 25.42 mg/100 mg and 25.31 mg/100 mg respectively. However, carbohydrate values of wheat seeds were recorded 23.04 mg/100 mg in *Everniastrm* and 22.21 mg/100 mg in *Parmotrema* decomposed soil. On the other hand, carbohydrate value of rice cultivated in *Parmotrema* decomposed soil was found higher and denoted by 18.28 mg/100 mg. This value is found lower in *Usnea* containing soil i.e. 15.95 mg/100 mg (Table 6; Fig. 6).

iii. **Fat:** Amount of fat in wheat seeds was recorded higher and approximately alike grown in *Usnea* and *Everniastrum* decomposed soil represented by 2.73 mg/100 mg and 2.57 mg/100 mg respectively. The wheat seeds cultivated in *Parmotrema* decomposed soil shows minimum 1 mg/100 mg fat. Value of fat was found lower in seeds grown in non-lichenized soil denoted by 0.88 mg/100 mg. Fat values of both the grains (i.e. wheat and rice) which were grown in *Usnea* decomposed soil was observed higher in comparison to other two lichen taxa represented by 2.73 and 0.43 mg/100 mg (Table 6; Fig. 6).

Discussion

In the present investigation only staple food crops (i.e. wheat and rice) were considered to notice the impact of lichen decomposed soil on their growth and yield because these crops are most commonly cultivated in the hilly areas of Uttarakhand state. In forest communities the process of nutrient cycling is known to vary with the composition of plants connected with litter breakdown and enzymatic conversions of organic substrates (Belyea, 1996; van der Krift, et al., 2002; Cheng, et al., 2003). Yield variations in both the soils i.e. lichenized and non-lichenized may be different due to nature of chemical elements of decaying matter (Arya, et al., 2017). Therefore, disparity in the soil biota and soil nutrients occurred in different plant communities (Aerts, 1997).

Value of soil macronutrients (main soil elements) in lichen decomposed soil was observed higher as compared to normal soil (Arya, et al., 2017). These elements are responsible for high crop production. Value of macronutrients in the soil such as K, N, P and pH was increased to its double and sometimes triple after decomposing lichens. Micronutrients of soil such as Zn, Mn, Fe, Cu and S also play an important role in the plant's life. These elements are useful to improve growth and development of plants. Plants get these elements from soil and water. In hilly areas crop rotation and desire of crop diversity trend reduces the quantity of these important nutrients in the soil. In such situation the amount of these nutrients in the soil can be improved by decaying lichen taxa in the soil.

Environmental conditions such as light, soil moisture, temperature and pH are known to affect seed germination (Chachalis and Reddy, 2000; Baskin and Baskin, 1988). Insignificant impact of lichenized soil on wheat seed germination can also be because any of environmental factor. When any of these environmental factors exceed the optimum tolerance, the result is stress, which in turn influences developmental, structural, physiological and biochemical processes of seed germination (Arya and Bargali, 2019).

This study concluded that lichen decomposed soil supports higher yield of wheat and rice due to their ability to improve soil nutrients. The study also showed that crops grown in non-lichenized soil possess higher values of protein and carbohydrate. But their higher production was found in crops cultivated under lichenized soil. Studies of Arya et al. (2017) and Kumar and Upreti (2008) showed that the lichen litter biomass was found higher in *Quercus* forest as compared to other. It clearly indicates that in high altitude areas where lichen growth is luxuriant and it falls like other tree litter can be utilized for agricultural manure purpose. It is noted that in some high altitude areas such as Urgam valley area of Garhwal region from Kalpeshwar to Dumak village (Rudranath) lichen litter are found in abundance lying as litter of higher trees. But these remote areas are botanically less explored. There is need to utilize this high quantity of naturally fallen lichen litter which can be promoted for better agricultural yield.

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