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*Full Length Research Paper*

# The effect of sulphur applications on nutrient composition, yield and some yield components of barley (*Hordeum vulgare* L.)

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**This study was carried out to investigate the effect of different sulphur applications on nutrient composition, yield and some yield components of barley during 2004-05 and 2005-06 winter seasons in Eastern Anatolia, Turkey. The trial was conducted in a randomized complete block design with three replications. The results indicated that grain yield, plant height, spike lenght, number of seed per spike, biological yield, harvest index, 1000-seed weight, protein ratio, P, Cu, Mn, Ca, Mg, Fe and Zn content in grain and shoot were significantly affected by the sulphur applications. The highest grain yield was obtained from 160 kg sulphur ha$^{-1}$ application as 3424 and 3411 kg ha$^{-}$1 in 2004-05 and 2005-06, respectively.**

**Key words:** Barley, *Hordeum vulgare*, sulphur, yield.

## INTRODUCTION

The barley is ranked second among the winter cereals in the World and Turkey in respect of production and total yield (Anonymous, 2005). Barley, which has 57 million ha sowing area and 139 million tonnes of production in the world, has 3.6 million ha sowing area and 9 million tons of production in Turkey. Average yield of 2500 kg ha$^{-1}$ in Turkey is higher than that of the World (2440 kg ha$^{-1}$). Barley has an important role in animal feeding in Turkey and little part of it is used in malt industry.

Fertilizing is one of the most important agricultural practices in grain production. Nitrogen and phosphorus are the basic fertilizers used commonly, whereas sulphur application is very little or non-existence in the production of barley in Turkey. Agricultural areas in the province of Van and its surroundings in which the trial was carried out, have low organic matter content and the pH is extremely high (Gülser, 1992). Organic fertilizers are not common and so sulphur fertilizing in cereal agriculture has very important role in this region.

In the calcareous soils, the uptake of nutrients by the plants decreases and thus some losses occur in the yield and yield components. In addition, the plants cannot benefit from the fertilizers applied: as the soil pH is getting closer to basic, usefulness of some macro- and micronutrient elements reduces in various ways (Aktas, 1994). It is known that the lime interacts with plant nutrients and makes them difficult to be used by the plants (Aydeniz, 1985). It is important to research the effect of change of pH made by sulphur reinforcement on usefulness of plant nutrients for limed alkaline soils. It has been detected for limed alkaline soils that the usefulness of soil phosphorus increases as the quantity of given sulphur increases (Kacar, 1984). The elemental sulphur which has been applied to the soil by agricultural activities is transformed into sulfate and thus the soil reaction decreases (Usta, 1995). The aim of this study is to investigate the effect of different elemental sulphur amounts on yield and some yield components of barley grown on calcerous soils.

## MATERIALS AND METHODS

The experiment was carried out during 2004-05 and 2005-06 winter seasons at the experiment fields of Faculty of Agriculture, Yuzuncu Yıl University, Van, Turkey. The climatic data were as follows: The average temperatures were 7.4 and 6.9°C, total precipitation 417.2

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and 357.9 mm and the relative humidity 66.8 and 64.7% for first and second growing periods, respectively (Anonymous, 2006).

Some physical and chemical properties of soils are given in Table 1. In both years, the soils were sampled to a depth of 0 - 30 cm of the soil, air-dried and sieved (2 mm) for analyses. Particle size distribution was determined by Bouyoucus (1951) hydrometric method. Carbonate, phosphorus, potassium and pH were determined by the methods described by Page et al. (1982). $SO_4$-sulfur by the methods of Fox et al. (1964). pH was by 1:2.5 soil-water suspension (Jackson, 1958), organic matter by modified Walkley Black method (Walkley, 1947), available phosphorus by the methods of Olsen et al. (1954), sodium, potassium, calcium and magnesium in an extraction of neuter ammonium acetate (Thomas, 1982), available iron, copper, zinc, and manganese by mixing with DTPA (Lindsay and Norvell, 1978).

The extracted samples were analyzed by atomic absorption spectrophotometer. Crude protein and phosphorus contents in the grain were determined by Kjehldahl (Bremner, 1965) and vanado molibdo phosphoric acid yellow color methods (Kacar, 1984), respectively. Ca, Mg, Fe, Zn, Mn and Cu were determined after wet digestion in a $H_2SO_4$-salicylic acid mixture. Ca, Mg, Fe, Zn, Mn and Cu analysis were done by atomic absorption spectrometry (AOAC, 1990).

In the trial, six different sulphur applications (0, 40, 80, 120, 160, and 200 kg ha $^{-1}$) were applied together with the sowing and effects of these applications on plant height, spike lenght, number of seed per spike, grain yield, biological yield, 1000 seed weight, harvest index, protein ratio, P, Cu, Mn, Ca, Mg, Fe and Zn content in the grain and shoot were measured. The trial was conducted in a randomized complete block design with three replications. Plot size was 1.0 x 5 = 5 $m^2$ and each plot consisted of five rows of 20 cm apart. At harvest, two outer rows in each plot and 50 cm from each side were left as borders and the three rows in the middle were harvested (Sehirali, 1988). A basic fertilizer of 40 kg N ha $^{-1}$ was given to each plot in sowing as ammonium nitrate. Seeds were sown by hand on 26/10/2004 and 15/10/2005 and were harvested by the sickle on 12/07/2005 and 07/07/2006 for first and second years, respectively. All calculations and measures were made according the methods given by Ciftci and Sehirali (1984). Measurements were made on the 10 sample plants chosen randomly from the each plots. The data were analyzed according to randomized complete blocks design and the differences between averages were tested at 5% significance level in accordance with Duncan Multiple Comparative Method (Düzgünes et al., 1987; SAS, 1998).

**Table 1.** Some physical and chemical properties of the soil.

| Soil properties | 2004-05 | 2005-06 |
|---|---|---|
| Texture | Sandy loam | Sandy loam |
| pH 1:2.5 | 8.90 | 8.70 |
| $CaCO_3$ (%) | 3.63 | 4.05 |
| Organic matter (%) | 0.66 | 0.46 |
| Olsen soil test P (mg/kg) | 28.83 | 29.53 |
| Na me $100g^{-1}$ | 0.91 | 0.85 |
| K me $100g^{-1}$ | 1.92 | 2.00 |
| Ca me $100g^{-1}$ | 7.75 | 7.60 |
| Mg me $100g^{-1}$ | 1.55 | 1.90 |
| Fe mg $kg^{-1}$ | 6.80 | 8.34 |
| Cu mg $kg^{-1}$ | 0.90 | 0.87 |
| Zn mg $kg^{-1}$ | 0.75 | 0.65 |
| Mn mg $kg^{-1}$ | 14.61 | 12.98 |
| $SO_4$-S mg $kg^{-1}$ | 1.2 | 1.3 |

## RESULTS AND DISCUSSION

The effect of different sulphur applications was statistically significant for both years. The plant heights ranged between 75.2 - 85.1 cm in the first year and 63.3 - 82.2 cm in the second year. The lowest plant heights were obtained from the control plots, whereas the highest values were obtained from the plots given 160 kg/ha sulphur (Table 2). Sutaliya et al. (2003) reported that the highest plant height was obtained from the rate of 45 kg S $ha^{-1}$ in barley. The sulphur application improved the soil structure and it increased the usefulness of other plant nutrients. Dewal and Pareek (2004) stated that the plant height increased as the doses increased and the highest plant height was obtained from the 40 kg S $ha^{-1}$ application in wheat. Chaudhary et al. (2003) reported that the highest plant height was obtained from 60 kg S $ha^{-1}$ application in wheat. Our results were in agreement with the findings of other researchers. The differences may be from the ecological conditions. The spike lenght ranged between 6.4 - 7.9 cm and 6.1 - 7.0 cm for the first and second years, respectively. The lowest values were obtained from the control plots, whereas the plots given 160 kg S $ha^{-1}$ gave the highest values. Sutaliya et al. (2003) stated that the highest spike length was obtained from 45 kg S/ha application. Dewal and Pareek (2004) reported that the plant height increased as the sulphur doses increased and the highest spike length was obtained from the 40 kg S $ha^{-1}$ application in the wheat. Gupta et al. (2004) reported that the highest spike length was obtained from 45 kg S $ha^{-1}$ application. Number of seed per spike ranged between 16.4 - 20 for the first year and 17 - 20.4 for the second year. The lowest seed numbers/ spike was obtained from the control plots for both years. Highest seeds numbers/spike were obtained from 160 kg $ha^{-1}$ sulphur in the first year and 120 kg $ha^{-1}$ sulphur in the second year. Sutaliya et al. (2003) found that the highest number of seed per spike was obtained from 45 kg S $ha^{-1}$ application. Dewal and Pareek (2004) reported that the number of seed per spike increased as the sulphur doses increased and they found the highest number of seed per spike with 40 kg S $ha^{-1}$ application in wheat. Gupta et al. (2004) reported that the highest number of seed per spike was obtained from 45 kg S $ha^{-1}$ application. Biological yield ranged between 7325 - 11368 kg $ha^{-1}$ for the first year and 8174 - 10019 kg $ha^{-1}$ for the second year. The lowest biological yield was obtained from the control plots and the highest biological yield was obtained from the 200 kg S $ha^{-1}$ application for both years. Withers et al. (1997) reported that inorganic S application increased straw yield of cereals by 34%. Our findings were in agreement with the findings of other researchers.

The grain yield ranged between 2253 - 3424 kg $ha^{-1}$ for

**Table 2.** Effects of different sulphur doses on the yield and some yield components of barley and pH in soil*.

| Parameter | Years | Sulphur Doses (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 40 | 80 | 120 | 160 | 200 |
| Plant height (cm) | 2004-05 | 75.2 c | 81.6 b | 83.8 a | 84.9 a | 85.1a | 82 b |
| | 2005-06 | 63.3 e | 70.6 d | 74.5 c | 79.2 b | 82.2 a | 73.4 c |
| Spike length (cm) | 2004-05 | 6.4 d | 6.8 cd | 7.2 bc | 7.5 ab | 7.9 a | 6.6 cd |
| | 2005-06 | 6.1 d | 6.3 c | 6.7 b | 6.9 ab | 7.0 a | 6.4 c |
| Number of seed per spike | 2004-05 | 16.4 d | 17.8 c | 18.7 bc | 19.8 ab | 20.0 a | 18.9 bc |
| | 2005-06 | 17.0 c | 19.0 b | 19.0 b | 20.4 a | 19.4 b | 19.1 b |
| Biological yield (kg ha$^{-1}$) | 2004-05 | 7325 d | 8142 cd | 8513 c | 9736 b | 10173 b | 11368 a |
| | 2005-06 | 8174 d | 8297 d | 9650 bc | 9439 c | 9729 b | 10019 a |
| Grain yield (kg ha$^{-1}$) | 2004-05 | 2253 d | 2712 c | 3175 b | 3328 a | 3424 a | 3157 b |
| | 2005-06 | 2936 e | 3024 d | 3189 bc | 3269 b | 3411 a | 3115 c |
| 1000 Seed weight (g) | 2004-05 | 46.0 d | 49.2 c | 50.0 bc | 51.2 ab | 51.4 a | 49.6 c |
| | 2005-06 | 46.2 d | 48.6 c | 50.3 b | 51.5 a | 51.4 a | 49.2 c |
| Harvest index (%) | 2004-05 | 30.3 c | 33.0 bc | 36.7 a | 33.7 b | 32.3 bc | 27.3 d |
| | 2005-06 | 35.3 ab | 36.0 a | 33.0 c | 34.0 b | 34.7 abc | 30.6 d |
| pH in soil | 2004-05 | 8.9 a | 8.6 b | 8.4 bc | 8.4 bc | 8.3 cd | 8.2 d |
| | 2005-06 | 8.7 a | 8.6 ab | 8.4 bc | 8.4 bc | 8.3 c | 8.2 c |

*For each row within each treatment, means follows by the same letter do not differ significantly at 5 % probability level.

the first year and 2936 - 3411 kg ha$^{-1}$ for the second year. The lowest grain yields were obtained from the control plots for both years. The highest grain yields were obtained from the plots given 160 kg S ha$^{-1}$ in the first year but, the difference with 120 kg S ha$^{-1}$ was not significant. Also, the highest grain yield was obtained from 160 kg S ha$^{-1}$ application for the second year. Sutaliya et al. (2003) stated that the highest grain yield was obtained from 45 kg S ha$^{-1}$ application in barley. Garcia et al. (1999) reported that the sulphur based fertilizers increased the yield. Al-Abdulsalam and El- Garavany (1998) indicated that the highest grain yield was obtained from 500 kg S ha$^{-1}$ application in barley. Conry (1997) stated that S application from the leaf had a minimum effect on the grain yield of barley. Sulphur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients. Therefore, the yield increases.

1000 seed weight ranged between 46.0 - 51.4 g for the first year and 46.2 - 51.5 g for the second year. The lowest 1000 seed weight was obtained from the control plots for both years. The highest 1000 seed weight was obtained from 160 kg ha$^{-1}$ sulphur application for the first year but, the difference with 120 kg S ha$^{-1}$ application was not statistically significant. The second year the highest 1000 seed weight was obtained from 120 kg S ha$^{-1}$ application but the difference with 160 kg ha$^{-1}$ sulphur application was not statistically significant. 1000 seed weight is a characteristic affected from the environmental conditions. Gupta et al. (2004) reported that the highest 1000 seed weight was obtained from 45 kg S ha$^{-1}$ application. Harvest index ranged between 27.3 - 36.7% for the first year and 30.6 - 36.0% for the second year. The lowest harvest index was obtained from the plots given 200 kg S ha$^{-1}$ applied for both years. The highest harvest index was obtained from 80 and 40 kg S ha$^{-1}$ applications for the first and second years, respectively. Inal et al. (2003) found that the highest harvest index was obtained from 20 kg S ha$^{-1}$ application in wheat. The effect of different doses of sulphur applications on soil pH was statistically significant. Increasing doses sulphur applications decreased soil pH (Table 2).

Protein ratio in grain ranged between 9.2 - 11.0 and 8.9 - 11.7% for the first and second year, respectively. The lowest protein ratio in grain was obtained from the control plots for both years. The highest protein ratio was obtained from 200 kg S ha$^{-1}$ application for both years but the values obtained from the 120 and 160 kg S ha$^{-1}$ applications in second year were also same statistical group. Protein ratio in shoot ranged between 1.7 - 3.2 and 1.5 - 3.4% for the first and second year, respectively. The lowest protein ratio in shoot was obtained from the control plots in both years. The highest protein ratio in shoot was obtained from 160 kg S ha$^{-1}$ application in first year, the highest protein ratio in shoot was obtained from 120 kg S ha$^{-1}$ application in second year, the differences between 120 and 160 kg S ha$^{-1}$ application was found statistically insignificant for both years. Protein ratio increased as the sulphur increased. In case of insufficient sulphur, the protein synthesis is prevented. It is understood that the plants which has insufficient sulphur, has low protein content but their amino acid content increases (Linser et al., 1964., Eppendorfer, 1968). Gupta et al. (2004) stated that the highest protein ratio was obtained from 45 kg S ha$^{-1}$ application in wheat. Chaudhary et al.

**Table 3.** Effects of different sulphur doses on the grain and shoot nutrient content of barley *.

| Nutrient | Years | Sulphur Doses (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 40 | 80 | 120 | 160 | 200 |
| Protein ratio (%) | 1. year shoot | 1.7 d | 2.1 c | 2.5 b | 3.0 a | 3.2 a | 2.5 b |
| | 2. year shoot | 1.5 d | 1.9 d | 2.4 c | 3.4 a | 3.2 ab | 2.9 b |
| | 1. year grain | 9.2 d | 9.4 cd | 9.5 cd | 9.8 c | 10.2 b | 11.0 a |
| | 2. year grain | 8.9 b | 9.8 b | 9.9 b | 11.4 a | 11.3 a | 11.7 a |
| P (%) | 1. year shoot | 0.16 e | 0.18 d | 0.22 c | 0.25 b | 0.29 a | 0.26 b |
| | 2. year shoot | 0.18 f | 0.2 0 e | 0.22 d | 0.26 c | 0.30 a | 0.28 b |
| | 1. year grain | 0.31 d | 0.35 c | 0.41 b | 0.45 a | 0.41 b | 0.37 d |
| | 2. year grain | 0.35 e | 0.38 d | 0.41 c | 0.51 a | 0.47 b | 0.38 d |
| Cu (mg $kg^{-1}$) | 1. year shoot | 10.1 e | 10.6 e | 13.5 d | 15.5 c | 26.4 b | 29.4 a |
| | 2. year shoot | 4.5 d | 5.1 d | 12.2 d | 16.8 b | 27.3 a | 28.0 a |
| | 1. year grain | 7.9 c | 10.7 b | 11.1 b | 17.1 a | 16.2 a | 12.6 a |
| | 2. year grain | 4.5 c | 4.8 c | 5.7 c | 10.8 b | 15.6 a | 16.5 a |
| Mn (mg $kg^{-1}$) | 1. year shoot | 18.7 bc | 16.2 c | 18.6 bc | 23.4 ab | 20.9 ac | 24.5 a |
| | 2. year shoot | 21.5 c | 23.3 bc | 25.2 ab | 27.1 a | 24 b | 26.9 a |
| | 1. year grain | 12.6 b | 12.7 b | 12.4 b | 15.1 b | 18.9 a | 20.1 a |
| | 2. year grain | 11.3 c | 11.6 c | 14.0 b | 14.6 ab | 15.4 a | 15.7 a |
| Ca (mg $kg^{-1}$) | 1. year shoot | 753.5 d | 1100.6 c | 1254.2 c | 1555.4 b | 2355.4 a | 2403.9 a |
| | 2. year shoot | 824 c | 957.1 c | 1224.8 b | 2356 a | 2433.8 a | 2448.7 a |
| | 1. year grain | 287.7 d | 274.8 d | 752 b | 499.3 c | 991.3 a | 790.9 b |
| | 2. year grain | 245.4 d | 252.4 d | 314.7 c | 360.9 b | 467.2 a | 482.2 a |
| Mg (mg $kg^{-1}$) | 1. year shoot | 651.9 c | 669.6 c | 683.7 c | 708.6 c | 842.5 b | 1074.5 a |
| | 2. year shoot | 652.2 f | 687.4 e | 729 d | 807.4 c | 1001.9 b | 1058.7 a |
| | 1. year grain | 656.3 d | 782.6 c | 920.8 b | 1058.2 a | 1123.6 a | 1023.5 a |
| | 2. year grain | 919.1 d | 923.4 d | 1157.9 c | 1266.8 bc | 1358.5 b | 1493.6 a |
| Fe (mg $kg^{-1}$) | 1. year shoot | 50.1 b | 60.4 b | 57.6 b | 80.9 a | 76.9 a | 82.1 a |
| | 2. year shoot | 125 | 103.4 | 63.6 | 61.0 | 91.9 | 92.6 |
| | 1. year grain | 47.5 | 37.9 | 40.9 | 49.6 | 55.4 | 49.5 |
| | 2. year grain | 44.8 d | 49.5 cd | 50.4 bc | 62.5 a | 67.2 a | 55.2 b |
| Zn (mg $kg^{-1}$) | 1. year shoot | 8.3 c | 10.4 c | 13.9 ab | 14.3 ab | 13 b | 15.6 a |
| | 2. year shoot | 12.7 c | 14.5 c | 16.7 b | 17.5 b | 20.8 a | 20.2 a |
| | 1. year grain | 16.9 | 18.0 | 18.1 | 15.9 | 19.5 | 17.1 |
| | 2. year grain | 12.7 e | 14.9 d | 18.5 c | 21.6 b | 22.8 ab | 23.3 a |

*For each row within each treatment, means follows by the same letter do not differ significantly at 5 % probability level.

(2003) reported that the highest crude protein ratio was obtained from 60 kg S $ha^{-1}$ application in wheat. Khan et al. (2003) who applied 0, 20, 40, 60, 80 and 100 kg S $ha^{-1}$ to wheat reported that the protein content increased as the sulphur dose increased. They found that the most economic dose was 20 kg S $ha^{-1}$. The effect of sulphur applications on phosphorus content of the grain and shoot were found statistically significant for both years. The lowest phosphorus content in the grain and shoot were obtained from the control plots. The highest phosphorus contents in shoot were obtained from 160 kg S $ha^{-1}$ application. An application of 120 kg S $ha^{-1}$ gave the highest phosphorus content in grain. 160 and 200 kg S $ha^{-1}$ applications did not increase the phosphorus content of grain; on the contrary they decreased it. It is known that sulphur fertilization improves the structure of soil in calcareous soils and increases the uptake of other plant nutrients. Sharma et al. (2004) stated that the highest phosphorus content in the grain was obtained from 20 kg $ha^{-1}$ gypsum and 30 kg $ha^{-1}$ pyrite applications.

The effect of sulphur applications on Cu, Mn, Ca and Mg contents of the shoot and grain were found statistically significant for both years. The lowest Cu contents in the shoot and grain were obtained from the control plots for both years. An application of 200 kg S $ha^{-1}$ gave the highest Cu content in shoot for both years but the value obtained from 160 kg S $ha^{-1}$ application in the second year was also in the same statistical group. In the first year, the highest Cu content in grain was obtained from 120 kg S $ha^{-1}$ application. The difference among 120,160 and 200 kg S $ha^{-1}$ applications were statistically insignificant. In the second year, the highest Cu content in grain was obtained from 200 kg S $ha^{-1}$ application. The difference between 160 and 200 kg S $ha^{-1}$ applications was statistically insignificant (Table 3). While the lowest Mn contents were obtained from control plots for shoot and grain in both years (except for shoot in first year), the highest Mn contents were obtained from 200 kg S $ha^{-1}$ applications for shoot and grain in both years. The difference between 160 and 200 kg S $ha^{-1}$ applications was statistically insignificant in grain of both years.

The lowest Ca contents in the shoot and grain were obtained from the control plots for both years. An application of 200 kg S $ha^{-1}$ gave the highest Ca content in shoot for both years. The difference between 160 and 200 kg S $ha^{-1}$ applications in first year and the differences among 120, 160 and 200 kg S $ha^{-1}$ applications were found statistically insignificant. In the first year, the highest Ca content in grain was obtained from 160 kg S $ha^{-1}$ application. In second year, the highest Ca content in grain was obtained from 200 kg S $ha^{-1}$ application. The difference between 160 and 200 kg S $ha^{-1}$ applications was statistically insignificant in second year (Table 3). While the lowest Mg contents in shoot and grain were obtained from control plots, the highest Mg contents in shoot and grain were obtained from 200 kg S $ha^{-1}$ applications. The differences among 120, 160 and 200 kg S $ha^{-1}$ applications in grain of first year were statistically insignificant.

The effect of sulphur applications on Fe contents of the shoot in second year and grain in first year were found statistically insignificant. The lowest Fe contents in shoot of first year and in grain of second year were obtained from control plots. In the first year, the highest Fe content in shoot was obtained from 200 kg S $ha^{-1}$ application. The difference among 120,160 and 200 kg S $ha^{-1}$ applications was statistically insignificant. In the second year, the highest Fe content in grain was obtained from 160 kg S $ha^{-1}$ application. The difference between 120 and 160 kg S $ha^{-1}$ applications was statistically insignificant (Table 3). The lowest Zn contents in shoot were found control plots in both years. In first year, the highest Zn content was obtained from 200 kg S $ha^{-1}$ application. In second year the highest Zn content was obtained from 160 kg S $ha^{-1}$ application. The difference between 160 and 200 kg S $ha^{-1}$ application was found statistically insignificant. The differences among S applications were statistically insignificant for Zn contents in grain in first year. While the lowest Zn content in grain was obtained from control plots, the highest Zn content in grain was obtained from 200 kg S $ha^{-1}$ application in the second year. Our findings were in agreement with those of Alpaslan et al. (2004).

## Conclusion

It has been observed that the sulphur-based fertilizer application in the calcareous and alkaline soils decreased the soil pH and improved the soil structure. In the calcareous soils, nutrient uptake by the plants decreases and thus some losses in yield and yield components occur. It was observed that sulphur fertilizer improved the soil partly and caused some good results in yield and yield components. It is suggested that, taking the economical dimension into account, 80 - 120 kg S $ha^{-1}$ fertilizer will lead to good results in these very alkaline soils of the region by decreasing pH and increasing the usability of other nutrients in growing barley.

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