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Research Article

# RESPONSE OF COMPACTION WITH SULPHUR FERTILIZATION TO NUTRIENT CONTENT, UPTAKE AND ECONOMICS OF BARLEY ON HIGHLY PERMEABLE SOIL

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**Abstract-** Coarse textured soils of arid and semi arid regions are highly permeable and loss of water as well as soluble nutrients especially sulphur is quite high from these soil. With this view, a field experiment was conducted on loamy sand soils to study the response of compaction (0, 2, 4 and 8 passes of 500 kg manually driven iron roller) and sulphur (0, 15, 30 and 45 kg S $ha^{-1}$) fertilization through gypsum on nutrient content, uptake, protein and economics of barley crop. Significant improvement in content and uptake of nitrogen, phosphorus, potassium, and sulphur were observed up to 4 passes of 500 kg iron roller and 30 kg S $ha^{-1}$. A significant increase in protein content in grain of barley was also observed under 4 passes of iron roller with 30 kg S $ha^{-1}$. Increased levels of compaction retained more amount of sulphate in 15-30 cm soil layers. Significantly higher net return (Rs. $ha^{-1}$) was fetched with the combined use of compaction by 4 passes of 500 kg iron roller and 30 kg S $ha^{-1}$. However, optimum level of S (49.96 kg $ha^{-1}$) was worked out higher in response study but a more realistic level of 30 kg S $ha^{-1}$ could be safely recommended with compaction for barley crop.

**Keywords**- Barley yield, Gypsum, Moisture conservation, Nutrients losses, Protein.

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## Introduction

Barley (*Hordium vulgare* L.) is one of the most important cereals of the world. Barley is generally grown on marginal and sub marginal sandy soils with low inputs in arid and semi arid region of western India, where the condition for wheat production is not favorable. In Rajasthan, it is grown on light textured soils, low in nitrogen and organic matter content with poor moisture and nutrient retentive capacity. The easiest way of boosting the productivity of the soil is through mechanical manipulation along with balance fertilization to the under nourished crop [1].

In addition to that, whatever amount of organic matter present is oxidized very fast due to high temperature and get lost because of high porosity, therefore, it is very difficult to have organic matter build up in these soil. Their moisture retentive capacity is also very low and more than one third of applied rain water gets lost by deep percolation [2]. Such these soil are prone to heavy losses of soluble nutrients, particularly that of $NO_3$-N, K and S. Compaction of sandy soil for minimizing percolation losses of nutrients and improve moisture storage in the soil [3]. Leaching losses and depletion of soil sulphur due to maximum cultivation of pulses and oil seed crops in cropping sequence, created a gap between supply and removal of sulphur on highly permeable sandy soil. Use of sulphur free fertilizer in intensively cropped areas, depletion of organic matter in soil which is supposed to be a reservoir of sulphur is also important for sulphur deficiency [4]. Cereals remove about 3-4 kg S per ton yield [5]. In Jaipur district of Rajasthan, where 8 ppm S by the Morgan method was taken as critical level, a study of 555 soil samples have shown that 21% soil had less than 8 ppm S, 30% had 8-16 ppm and rest more than 16 ppm and reported S deficiency[6]. Keeping these facts, an investigation was conducted to evaluate the response of compaction and sulphur fertilization on nutrient status of barley and its economics. Looking to the importance of S deficiency and constraints associated with soil an experimental on appropriate tillage in combination with sulphur levels generate a suitable technology in order to have maximum utilization of water and nutrient under present condition of soil system.

## Materials and Methods

A field experiment was conducted at agronomy farm of S.K.N. College of Agriculture, Jobner. The soil of the experimental site was sandy loam (situated at 26.06° N latitude and 75.28° E longitude) with bulk density 1.49 $Mgm^{-3}$, saturated hydraulic conductivity 10.2 cm $hr^{-1}$, total porosity 43.8%, and moisture content at 1/3 bar 11.0%. The soil having pH 8.0, organic carbon 0.15%, and low in available nitrogen (128 kg $ha^{-1}$), phosphorus (16.8 kg $ha^{-1}$), medium in K (187 kg $ha^{-1}$) and S (9.0 mg $kg^{-1}$ soil).

The treatment consists of four levels of compaction including no compaction ($C_0$) as practiced by farmer, two passing ($C_2$) and four passing ($C_4$) and eight passing ($C_8$) of 500 kg iron roller at proctor moisture in main plot, whereas four levels of sulphur i.e. no sulphur ($S_0$), 15 ($S_{15}$), 30 ($S_{30}$) and 45 ($S_{45}$) kg S $ha^{-1}$ and were replicated four times in split plot design. Barley seed (RD-2552) was sown with the help of plough at a depth 4-5 cm with row to row distance of 22.5 cm. A uniform basal dose of N @ 80 kg $ha^{-1}$, P @ 40 kg $ha^{-1}$ and K @ 40 kg $ha^{-1}$ through urea, diammonium phospahate and muriate of potash in all the plots were applied, respectively where as sulphur was applied through gypsum as per treatment at 21 days before sowing and incorporated in the soil. The soil parameters were analyzed following standard analytical procedures [7]. Grain and straw samples were washed thoroughly, dried at 60 °C, finely grounded and digested in diacid mixture of $HNO_3$ and $HClO_4$ in 9:1 ratio for the analysis of all other elements except N. Nitrogen was determined by colorimetric method using Nesseler's reagent; phosphorus was estimated by vanadomolybdate yellow colour method and potassium was estimated on flame photometer [7]. Sulphur content was determined by colorimetrically turbidimetric method using $BaCl_2$ [8]. Protein content of barley grain was worked out by multiplying N content of grain by a factor of 6.25 [9]. The quadratic response function $Y=b_0+b_1S+b_2S^2$ was fitted to describe grain yield as a function of sulphur fertilizer.

### Statistical analysis

The observation recorded for different aspects of crop and statistically analyzed in split plot design [10]. Significance of the treatment effect was tested through "F" test along with appropriate standard error of mean (SEm±) and critical difference (CD) were prepared.

## Results and Discussion

### Nutrient content

Effect of compaction and sulphur levels on per cent nitrogen (N), phosphorus (P), potassium(K) and sulphur (S) content in grain and straw of barley [Table-1].The maximum N, P, K and S content were observed under $C_8$ (compaction by 8 passes of 500 kg iron roller) in grain and straw of barley as compare to other treatments. Data further reveal that the treatment $C_4$ was found to be statistically at par with that of $C_8$ treatment with respect to N, P, K, and S content in grain and straw of barley crop. The above observations indicate that the per cent N, P, K, and S content in grain increased significantly due to compaction treatment. It might be due to the increased availability of moisture and nutrients especially N, P, K, and S in the soil with compaction treatment which resulted in reduced nutrients leaching owing to increase in bulk density of the sub-surface soil, which in turn resulted in more retention by soils and greater absorption of nutrients as well as its efficient utilization by crops due to better root proliferation, vegetative growth, grain yield and straw yield compared to no compaction treatment [11-12].

Among the sulphur levels, the treatment receiving 30 kg S ha$^{-1}$ recorded the significantly higher content of N, P, K and S in grain and straw and it was significantly superior over 45 kg S ha$^{-1}$, 15 kg S ha$^{-1}$ and control. Increasing levels of sulphur significantly increased the percent N, P, K and S content in grain and straw, which might be attributed to the application of S which might have improved the nutritional environment in the rhizosphere as well as in plant system [13-14] and consequently increased the availability of nutrients in the root zone coupled with increased metabolic activity at cellular and their translocation especially to reproductive organs which ultimately increased the concentration of nutrients (N, P, K & S) in different plant parts of crop including grain and straw.

**Table-1** *Effects of compaction and sulphur levels on N, P, K, S and protein content of barley*

| Treatments | N content (%) | | P content (%) | | K content (%) | | S content (%) | | Protein content in grain (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | |
| $C_0$ | 1.61 | 0.437 | 0.348 | 0.093 | 0.469 | 1.218 | 0.153 | 0.096 | 10.06 |
| $C_2$ | 1.76 | 0.510 | 0.367 | 0.102 | 0.516 | 1.261 | 0.161 | 0.101 | 10.98 |
| $C_4$ | 1.89 | 0.572 | 0.387 | 0.110 | 0.555 | 1.296 | 0.168 | 0.105 | 11.81 |
| $C_8$ | 1.94 | 0.597 | 0.388 | 0.114 | 0.562 | 1.317 | 0.170 | 0.106 | 12.14 |
| SEm± | 0.034 | 0.017 | 0.004 | 0.002 | 0.010 | 0.010 | 0.002 | 0.001 | 0.213 |
| CD (p=0.05) | 0.109 | 0.053 | 0.013 | 0.008 | 0.033 | 0.033 | 0.007 | 0.004 | 0.682 |
| $S_0$ | 1.65 | 0.455 | 0.346 | 0.091 | 0.488 | 1.222 | 0.155 | 0.097 | 10.30 |
| $S_{15}$ | 1.78 | 0.517 | 0.367 | 0.102 | 0.520 | 1.263 | 0.162 | 0.101 | 11.13 |
| $S_{30}$ | 1.87 | 0.560 | 0.384 | 0.111 | 0.540 | 1.294 | 0.167 | 0.104 | 11.69 |
| $S_{45}$ | 1.90 | 0.584 | 0.389 | 0.115 | 0.554 | 1.313 | 0.168 | 0.106 | 11.89 |
| SEm± | 0.026 | 0.012 | 0.003 | 0.002 | 0.006 | 0.008 | 0.002 | 0.0010 | 0.162 |
| CD (p=0.05) | 0.074 | 0.035 | 0.010 | 0.007 | 0.018 | 0.022 | 0.005 | 0.0029 | 0.464 |

### Protein content

Soil compaction and sulphur levels were significantly increased protein content in grain of barley [Table-1]. Protein content of grain was observed as minimum under no compaction (10.06%) and maximum values were noted under $C_8$ (12.14%). The per cent rise in protein content in grain was in order of 20.65, 17.39 and 9.16 under $C_8$, $C_4$ and $C_2$ respectively over that of control treatment. The $C_4$ was found to be statistically at par with that of $C_8$ with respect to protein content. The favorable effect of compaction on protein content might be probably due to the fact that increasing availability of N and other nutrients in soil with sufficient moisture which increased the proportion of portentous substances in the sink [15].

Application of 30 kg S ha$^{-1}$ significantly increased the protein content (11.69 %) and it was statistically at par with 45 kg S ha$^{-1}$. Application of sulphur @ 45, 30 and 15 kg ha$^{-1}$ has produced 15.48, 13.50 and 8.04 per cent more protein content in grain respectively over that of no S application. This might be due to increase availability of sulphur as well as nitrogen as both the elements promote protein synthesis. Sulphur is a constituent of amino acids *viz.*, cystine, cystein and methionine. It also helps in conversion of these amino acids into high quality protein [16]. Sulphur increased the mobilization of proteins stored in leaves and stems and also promoted the translocation of the nitrogenous degradation compounds towards the grain. Application of sulphur also increased availability of sulphur to plants which might have resulted in profused shoot and root growth and thereby activating greater absorption of nitrogen [17].

### Nutrient uptake

The results on N, P, K and S uptake by grain and straw of barley as influenced by compaction and sulphur levels are presented in [Table-2]. The N, P, K and S uptake by grain and straw was remarkably higher with all the compaction and sulphur treatment over control. Among the treatments, the highest nutrient uptake by grain was in order of 81.60, 16.26, 23.60 and 7.12 kg ha$^{-1}$ and that of straw 38.69, 7.50, 84.45 and 6.79 kg ha$^{-1}$ was observed for N, P, K and S, respectively over that of control. The overall mean improvement in N, P, K and S uptake by grain and straw due to $C_8$ was higher 77.58, 63.75, 76.40 and 63.31 as well as 99.57, 81.40, 57.21 and 60.46 respectively over that of control ($C_0$). The treatment $C_4$ was found to be statistically at par with that of $C_8$ treatment with respect to N, P, K and S uptake by grain and straw of barley crop. The nutrient uptake (N, P, K and S) increased with compaction due to the maintained the optimum moisture in coarse textured soil by checking the nutrient losses owing to favourable physical properties (increased bulk density and decreased saturated hydraulic conductivity) which has resulted in greater utilizations of all the nutrients by plant and has also produced better root growth, root proliferation, grain and straw yield compared to uncompacted control. This may be attributed to the maximum root growth resulting in increased contact between absorbing root and soil solution of nutrients, increased continuity of water films including a less tortuous path and increased rate of movement [18-19]. Compaction was beneficial not only in retaining the moisture but also retaining the ample quantity of nutrients for plant use. Compaction of loamy sand soil was found effective in minimizing the down ward movement of nitrogen and potassium under 12 passing of 500 kg iron roller [12]. It means that the compaction increased the concentration of nutrients (N, K and S) in the soil and thus the available nutrients are easily absorbed by the plants [15].

The highest uptake of N, P, K and S by grain and straw was observed under $S_{45}$

(45 kg S $ha^{-1}$) than rest of treatments. Significantly increased in the nutrient uptake (N, P, K and S) by grain and straw recorded under $S_{30}$ (30 kg S $ha^{-1}$) but statistically at par with that of $S_{45}$ treatment. Nutrients uptake were increased as a result of sulphur fertilization to increase the availability of nutrients in the plots receiving S due to conducive environment in rhizosphere and solubilization of nutrients in the soil leading to higher absorption of nutrients by the plants. Reverse is the consequence increased nutrient uptake will results in higher dry matter [13].

**Table-2** *Effects of compaction and sulphur levels on N, P, K and S uptake by barley*

| Treatments | N uptake (kg $ha^{-1}$) | | P uptake (kg $ha^{-1}$) | | K uptake (kg $ha^{-1}$) | | S uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| $C_0$ | 45.95 | 19.39 | 9.93 | 4.14 | 13.38 | 53.72 | 4.36 | 4.23 |
| $C_2$ | 59.41 | 26.20 | 12.39 | 5.24 | 17.43 | 64.44 | 5.43 | 5.15 |
| $C_4$ | 75.64 | 35.15 | 15.31 | 6.76 | 22.18 | 78.96 | 6.71 | 6.39 |
| $C_8$ | 81.60 | 38.69 | 16.26 | 7.50 | 23.60 | 84.45 | 7.12 | 6.79 |
| SEm± | 2.50 | 1.86 | 0.38 | 0.28 | 0.74 | 2.38 | 0.17 | 0.21 |
| CD (p=0.05) | 8.01 | 5.96 | 1.22 | 0.89 | 2.37 | 7.60 | 0.56 | 0.68 |
| $S_0$ | 49.72 | 21.22 | 10.43 | 4.37 | 14.75 | 56.46 | 4.68 | 4.48 |
| $S_{15}$ | 62.45 | 27.76 | 12.82 | 5.45 | 18.24 | 67.06 | 5.66 | 5.36 |
| $S_{30}$ | 73.55 | 33.72 | 15.01 | 6.64 | 21.21 | 76.65 | 6.52 | 6.16 |
| $S_{45}$ | 76.88 | 36.72 | 15.64 | 7.19 | 22.38 | 81.40 | 6.76 | 6.57 |
| SEm± | 1.78 | 1.21 | 0.27 | 0.19 | 0.47 | 1.66 | 0.13 | 0.15 |
| CD (p=0.05) | 5.11 | 3.47 | 0.78 | 0.56 | 1.33 | 4.76 | 0.38 | 0.44 |

## Sulphur retention

The data on mobility and retention of $SO_4^{2-}$ [Table-3] showed that sulphate content in 0-15, 15-30 and 30-45 cm soil layer increased substantially due to compaction treatments as compared to uncompacted (control). It could be observed from the mean data that the maximum retention of $SO_4^{2-}$ (10.33 mg $kg^{-1}$) was observed under $C_8$ (compaction by 8 passing of 500 kg iron roller) with sulphur application at the rate of 45 kg S $ha^{-1}$ in 15-30 cm soil layer followed by 30-45 and 0-15 cm as compared with other treatment combination at harvest stage of barley crop.

**Table-3** *Effect of compaction and sulphur levels on retention and mobility of $SO_4^{2-}$ in soil at harvest stage of barley*

| Treatments | | $SO_4^{2-}$ (mg $kg^{-1}$) at harvest Soil Depth(cm) | | |
|---|---|---|---|---|
| | | 0-15 | 15-30 | 30-45 |
| $C_0$ | $S_0$ | 5.22 | 5.40 | 5.55 |
| | $S_{15}$ | 5.54 | 5.67 | 5.80 |
| | $S_{30}$ | 5.74 | 5.95 | 5.07 |
| | $S_{45}$ | 5.90 | 5.06 | 6.15 |
| $C_2$ | $S_0$ | 6.31 | 6.70 | 6.52 |
| | $S_{15}$ | 6.43 | 7.00 | 6.64 |
| | $S_{30}$ | 6.60 | 7.15 | 7.02 |
| | $S_{45}$ | 6.72 | 7.22 | 7.13 |
| $C_4$ | $S_0$ | 7.45 | 7.92 | 7.41 |
| | $S_{15}$ | 7.58 | 8.18 | 7.48 |
| | $S_{30}$ | 7.71 | 8.35 | 7.60 |
| | $S_{45}$ | 7.88 | 8.49 | 7.86 |
| $C_8$ | $S_0$ | 8.60 | 9.01 | 8.25 |
| | $S_{15}$ | 8.73 | 9.42 | 8.80 |
| | $S_{30}$ | 8.99 | 9.87 | 9.08 |
| | $S_{45}$ | 10.11 | 10.33 | 10.05 |

Compaction of loamy sand soil is more effective in minimizing the down ward movement of sulphur. This might be due to increase in bulk density of respective soil layers owing to compaction. Since solubility of sulphur containing fertilizer was very high in such situation soluble sulphur ions leached below the root zone [20]. Compaction was as an alternative treatment to maintain large quantity of nutrient retention and moisture content of sandy soil. Surface compaction greatly retards the mobility of soluble nutrient and helps in retention of mobile nutrient in soil for longer duration [12]. Generally, period wise decline $SO_4^{2-}$ concentration could be attributed partly to its removal by plant and partly to the losses in post harvest soil [21]. However, in our study 45 kg S $ha^{-1}$ treatment approached to threshold mean value of 7.6 mg $kg^{-1}$ available sulphur in 0-15 cm layer of post harvest soil [22].

## Economics

The data presented in [Table-4] shows that levels of compaction and sulphur as well as their combination had significant influence on economic (on net return) of barley. The significantly highest net return per hectare was recorded with compaction by 4 passes (Rs. 24817) followed by compaction by 8 passes (Rs. 24439) as compared to 2 passes (Rs. 19881) and control (Rs. 16373). In case of sulphur, the maximum net return (Rs. 25188 $ha^{-1}$) was found under $S_{45}$ (45 kg S $ha^{-1}$) but it was statistically at par with application of 45 kg S $ha^{-1}$. The application of 15, 30 and 45 kg S $ha^{-1}$ registered an increase in net return of Rs. 4159, 8013 and 9138 $ha^{-1}$, respectively as compared to control. The results show that application of 30 kg S $ha^{-1}$ gave significantly higher net return in comparison to other treatment. So, application of 30 kg S $ha^{-1}$ was best dose for barley grown on loamy sand soil and it is found most profitable from economic point of view when compared with the higher dose of sulphur application.

**Table-4** *Effect of compaction and sulphur levels on net return (Rs. $ha^{-1}$) of barley*

| Treatments | $S_0$ | $S_{15}$ | $S_{30}$ | $S_{45}$ | Mean |
|---|---|---|---|---|---|
| $C_0$ | 12965 | 15379 | 17963 | 19185 | 16373 |
| $C_2$ | 15901 | 19124 | 21401 | 23100 | 19881 |
| $C_4$ | 18643 | 23526 | 28158 | 28942 | 24817 |
| $C_8$ | 16691 | 22810 | 28730 | 29525 | 24439 |
| Mean | 16050 | 20209 | 24063 | 25188 | |
| SEm± | C=499 | S=418 | I=1184 | II=1245 | |
| CD (p=0.05) | C=1599 | S=1198 | I=2393 | II=2519 | |

I= CD at 5% for compaction at same levels and sulphur at different levels
II= CD at 5% for compaction at different levels and sulphur at same levels or both

The treatment combination $C_8S_{45}$ (8 passes of 500 kg iron roller with 45 kg S $ha^{-1}$) gave maximum net return (Rs. 29525 $ha^{-1}$), whereas lowest net return (Rs. 12965 $ha^{-1}$) was recorded under $C_0S_0$ (no compaction and sulphur) treatment combination. The data further show that the treatment combination $C_8S_{30}$, $C_4S_{45}$ and $C_4S_{30}$ were found to be statistically at par with $C_8S_{45}$. This finding revealed that low levels of compaction and sulphur application ($C_4S_{30}$ treatment combination) could give significantly higher net return as compare to higher levels of compaction and sulphur application. The results so obtained indicate that $C_4S_{30}$ treatment combination was profitable from economic point of view.

## Response studies

To describe the relation between grain yield (Y) and applied sulphur fertilization, multiple regression studies were under taken by a quadratic relationship type:

$$Y=b_0+b_1S+b_2S^2$$

Describing grain yield (Y) as a function of main effect of sulphur (S), which also showed a curvilinear trend expressed as a second degree polynomial. The predicted yield work out form this quadratic function showed very high closeness to the observed data as evidenced from very high value of $R^2$ (0.9959** significant at 1 % level). The partial regression coefficient ($b_0$=2980, $b_1$=41.06 and $b_2$= -0.041) in Kg $ha^{-1}$ were found to be significant. A level of 49.96 kg S $ha^{-1}$ was found to be optimum level with grain yield of 4019 kg $ha^{-1}$. Thus, the response to optimum level of S was found 138 kg more grain yield than grain yield received 3881 kg $ha^{-1}$ under the application of 30 kg S $ha^{-1}$ through gypsum [Fig-1]. The optimum level of S was found to be appreciably higher than worked out level 30 kg $ha^{-1}$ in statistically analysis of this experiment. In fact, the low cost of gypsum as S source raised the optimum level of sulphur considerably. Despite yielding highest returns in present study, the optimum level of sulphur so determined could be considered too, high to be recommended in view of year to year fluctuation in productivity and input output prices concomitant with its on trustworthiness due to its estimation by extrapolation [23]. The grain yield data revealed only marginal improvement in yield at S level beyond 30 kg $ha^{-1}$. Therefore, to be on safer side and to make the fertilizer use more gainful covering larger crop area, a more realistic level of 30 kg S $ha^{-1}$ could be safely recommended for barley crop.

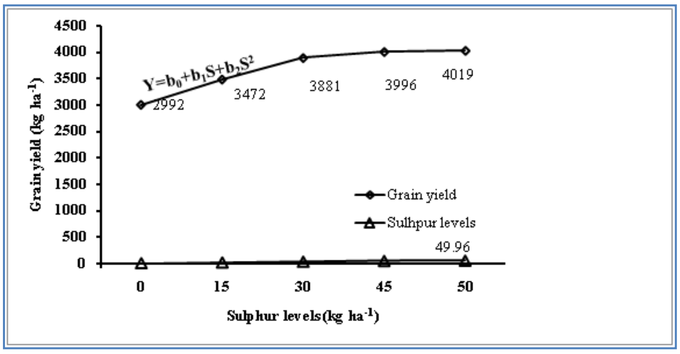


**Fig-1 Grain yield of barley crop as a function of sulphur fertilization**

## Conclusion

On the basis of experiment, it was concluded that compaction by 4 passing of 500 kg iron roller and application of 30 kg S $ha^{-1}$ was found beneficial in increasing the nutrients content (N, P, K and S), protein content in grain and their uptake by grain and straw of barley under semi arid region. Sulphur retention was increased with compaction levels. From economic point of view, compaction of soil by 4 passes of 500 kg iron roller along with application of 30 kg S $ha^{-1}$ was found to be best treatment combination for barley crop. The yield data also revealed that only marginal improvement in yield at S level beyond 30 kg $ha^{-1}$. In response studies, optimum level of S was found to be appreciably higher than worked out level 30 kg $ha^{-1}$ in statistically analysis of this experiment but a more realistic level of 30 kg S $ha^{-1}$ could be safely recommended with compaction for barley crop.

**Conflict of Interest: None declared**

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