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# Phenetic resistance in sugarcane, tentative conclusions and new research directions

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## Abstract
Sugarcane genotypes selected on the basis of dead hearts formation were studied for phenetic based characters of resistance. Shoot borer preferred to bore accessions/cultivars with light green and drooping foliage as well as droopiness of canopy seems to have been preferred over erectness. Low intensity of light reflected by leaves at 60 days after planting (DAP) in least susceptible group as compared to moderately susceptible and highly susceptible genotypes varying from 1.32x10 lux (Co H 70) to 1.46x10 lux (Co J 64) than the least susceptible. Apart from other leaves characteristics the leaf size has also been observed to be significantly related to borer attack, the short and broad leaves facilitating higher infestation than the long and narrow leaves. In present investigation, a gradual decline in sheath hardness with an increase in shoot borer susceptibility indicated a strong inverse correlation between sheath hardness and shoot borer incidence. The average spindle length of least susceptible (17.9 cm) and moderately susceptible (17.5 cm) entries at 60 DAP was higher than the highly susceptible genotypes (13.7cm). The susceptible variety Co1148 recorded the shortest spindle length (12.9 cm) indicating that genotypes with longer spindles were shown to offer greater resistance to *Chilo infuscatellus* damage than those with shorter spindles. In highly susceptible genotypes, the average chlorophyll content was recorded to be 27.7 mg/gm fresh weight as against 33.1 mg/gm observed in least susceptible. A consistent increase in total chlorophyll content was evident with in shoot borer resistance, being maximum in least susceptible entries and minimum in highly susceptible ones.

**Keywords:** Sugarcane, early shoot borer, resistance, morphological, physiological, phenetic characters

## Introduction
Sugarcane being a long duration crop is liable to be attacked by a number of insect pests and diseases which results in declines of sugarcane production by approximately 20.0 per cent by insect-pests. India was the second largest producer of sugar in the world after Brazil in 2015-16 [1]. India produced around 350 million tonnes of sugarcane and 25 million tones of sugar [2]. In 2016-17, area was 43. 89 lakh ha with average cane productivity of 69.88t/ha and production was 3067.2 lakh tones [3]. Out of more than half dozen lepidopterous tissue borers; these lepidopterous species, inflict severe losses in cane yield and sugar recovery [4] as they eat their way along the spindle/stems killing shoots, impairing growth, destroying buds and facilitating breakage of canes; the crambid moth borer, *Chilo infusatellus* Snellen (crambidae: lepidoptera) commonly known as shoot borer in North Indian sugarcane belt and as early shoot borer in peninsular India is chronic and of wide occurrence, infesting the *eksali* or spring planted crop during its early stages of growth (March to June) and *adhsali* crop during September to October, every year. In parts of Rajasthan, it also infests millable canes particularly in years of drought or scanty rainfall. Damage done by *C. infuscatellus* results in killing of mother shoot causing formation of dead hearts and thereby creating a gap in sugarcane field that ranges from 30 to 75 per cent in early stage of the crop (May-June) in subtropical India [5].

The increased vulnerability of most of the high sugared and high yielding genotypes owing to unscrupulous use of chemical pesticides have brought imbalances in biotic system resulting into development of resistance by insect-pests, loss of bio-diversity especially parasites and predators combining with resurgence of pests and secondary pest outbreaks simultaneously arising problems of environmental pollution, contamination of food chain, human and animal health hazards. A paradigm shift in pest control strategies from unilateral chemical approach to Non-chemical methods such as biological control, ecological management or host plant

Resistance has, therefore, become imperative. An experiment was laid to estimate the factors of phenetic resistance in sugarcane.

## Materials and Methods

Field experiment was laid down at Research Farm, CCS HAU, Regional Research Station, Karnal on second fortnight of March, 2014 with the objective to analyse the impact of sugarcane plant characters imparting some sort of resistance against arthropods especially infesting sugarcane crop. Three budded sets of sugarcane genotypes were planted in randomized block design with three replicates each in furrow drawn at a spacing of 75 cm. Dead hearts counts due to *Chilo infuscatellus* was recorded at 60 and than at 90 days after planting alongwith other field's observation by adopting standard procedure of observation. For the reflection of light intensity from third and fourth leaves was measured using photo sensor (Make: LI-COR Instrument, Model: LI-185B). The photo sensor was placed on upper surface of test leaves and deflection of light intensity by leaf surface was measured in Lux.

## Results and discussion

Plant resistance has a vital place in integrated pest management of field crops. It has become increasingly important to understand the interactions between insect-pests and host plants for building foundation of breeding programme for resistance.

The young virgin moth of *Chilo infuscatellus* have been reported to oviposit generally on the ventral side of the third and fourth leaf from the base of shoot [6]. Keeping this in the view some of their morphological characters have been studied in relation to borer incidence. The data of sugarcane accessions and cultivars chosen to investigate for their morphological characteristics are presented in table 1.

**Leaf Colour:** The least susceptible cultivars CoS 767 as also accession Co 87263 possessed darker leaves than moderately susceptible CoH 2, CoH 15 and CoH 99. The widely grown high sugared early maturing cultivar CoJ 64 and also the accession CoH 70 with high susceptibility to shoot borer had light green leaves. However, the highly susceptible, medium sugared late maturing cultivar Co 1148 and accession CoH 108 appeared moderately green (table 1).

**Shape of canopy:** The least susceptible variety CoS 767 and accession Co 87263 showed erect canopy. The canopy also tend to be almost erect in moderately susceptible accession CoH 2, CoH 15 and CoH 99, but all the highly susceptible cultivars *viz.*, Co 1148, CoJ 64, CoH 70, CoH 108 as also the moderately susceptible CoH 92 had drooping leaves (table 1).

As the result pointed out that shoot borer preferred to bore accessions/cultivars with light green and drooping foliage, although no resistance mechanism among crop plants have been specifically associated with plant shape, yet the droopiness of canopy in sugarcane seems to have been preferred over erectness as this perhaps offered better shelter/hiding under adverse climatic condition as well as from natural enemies, parasites, predators etc. As early as 1962, reports [7] on preference of shoot borer, *Chilo infuscatellus* for Co clones with droopy foliage available. Preferences for yellow green over the green plants by pea aphid, *Acyrthosiphon pisum* has been reported [8]. Similarly, light green and droopy foliage has been observed [9] in case sugarcane top borer, *Scirpophaga excerptalis* and aphid in wheat [10]. In Co clones of sugarcane, however, it has been reported [11] that *C. infuscatellus* avoids ovipositioning in pale green leaves.

**Reflection light:** The data presented in table show that the light intensity reflected by leaves at 60 days after planting (DAP) ranged from 1.2x10 lux (Co 87263) to 1.28x10 lux (Cos 767) in least susceptible group. The moderately susceptible accessions/cultivars reflected comparatively more light (1.25x10 lux to 1.42x10 lux) than least susceptible genotypes. And highly susceptible gen otypes reflected significantly higher range of light varying from 1.32x10 lux (CoH 70) to 1.46x10 lux (CoJ 64) than the least susceptible. A significant positive correlation was observed between intensity of light and susceptibility of genotypes to shoot borer (table 1).

In the present study light coloured leaves have been observed reflecting more light than the dark coloured leaves. The significant positive correlation between the amount of light reflected by the leaves of various test accessions/cultivars and shoot borer susceptibility also seems to support the present observations that generally the genotypes with dark leaf colour were less susceptible to *C. infuscatellus* than those with light green coloured leaves.

**Leaf length and Leaf width:** Significant differences in leaf length were discernible in accessions/cultivars of differential susceptibility. The highly susceptible genotypes recorded an average leaf length of 61.6 cm, which was significantly lower than the average leaf length of moderately susceptible (64.7 cm) and least susceptible group (68.4 cm). A significant negative correlation was apparent between shoot borer attack and leaf length (table 1).

Leaf width in least susceptible genotypes ranged from 1.58 cm (Co87263) to 1.83 cm (CoS 767) and moderately susceptible from 1.75 cm (CoH 15) to 2.35 cm (CoH 2). The moderately and highly susceptible genotypes were generally observed to possess comparatively wider leaves than least susceptible, save for highly susceptible cultivars CoJ 64, which had the narrowest leaf blade.

Apart from other leaves characteristics the leaf size has also been observed to be significantly related to borer attack, the short and broad leaves facilitating higher infestation than the long and narrow leaves. While significant negative correlation was evident between leaf length and borer incidence, it was positive with leaf width. Observations of Rao testify the present record of sugarcane varieties that broad leaves are vulnerable to heavy shoot borer attack than those with narrow leaves [7]. A negative correlation have also been reported [9] between leaf length and per cent dead hearts formed due to top borer, *S. excerptalis* in sugarcane.

**Leaf sheath hardness:** At 45 DAP, hardness of leaf sheath in genotypes of differential susceptibility was found to vary from 1.87 kg/cm$^2$ (CoH 70, highly susceptible) to 2.84 kg/cm$^2$ (Co 87263, least susceptible). The least susceptible genotypes possessed harder leaf sheath than the moderately or highly susceptible cultivar/accession. A highly significant and negative correlation was evident between borer incidence and leaf sheath hardness. At 60 DAP, the outermost and next inner leaf sheath of least susceptible cultivar COS 767 and accession Co 87263 required an average force of 3.35kg/cm$^2$ and were observed to be hardest. The force applied to puncture the sheath of moderately susceptible genotypes ranged between 2.81(CoH 92) to 3.56 kg/cm$^2$ (CoH 15) with an average of 3.15 kg/cm$^2$, whilst highly susceptible genotypes required much lesser force 2.15 (CoH 70) to 2.71 kg/cm$^2$ (CoJ 64) than the least and moderately susceptible one. A gradual decline in sheath hardness with an increase in shoot borer susceptibility indicated a strong inverse correlation between sheath hardness and shoot borer incidence. The varieties Co 1148, CoJ 64 and genotypes CoH 70 and CoH 108with softer leaf sheath hardness were found to be heavily infested by *C. infuscatellus* than CoS 767, Co 87263, CoH 2, CoH 15, CoH 92 and CoH 99 (table 2 and 3). In case of other borer species, also the rind, spindle or stem hardness have implicated in conferring resistance, owing to which larvae perhaps finding it difficult to bore hard tissues of sugarcane [12, 13, 14].

**Moisture:** At 45 DAP, albeit of wide fluctuations in the shoot moisture content of different genotypes occurred in the shoot moisture level of least, moderately and highly susceptible genotypes, a marginal decrease in average water contents of shoot was recorded with susceptibility. The shoot of least susceptible genotypes contained an average of 63.85 per cent moisture level as against 62.7 and 61.8 per cent recorded in moderately and highly susceptible genotypes. A non-significant negative correlation was observed between borer susceptibility and available shoot moisture. In general, a higher shoot moisture level was observed at 60 DAP and varied marginally in three susceptible category. The least susceptible genotypes contained an average shoot moisture per cent 70.9 in comparison with 70.8 and 68.8 per cent recorded with moderately and highly susceptible genotypes, respectively (table 2 and 3). The slight variations in average shoot moisture in susceptibility groups pointed out a non-significant relationship between susceptibility level and shoot moisture. The shoot moisture dies not seem to play much role in shoot borer susceptibility. The mean shoot moisture content of least, moderately and highly susceptible genotypes showed slight differences, albeit of showing wide variations among the genotypes of equal susceptibility, a marginal decrease in average shoot moisture with susceptibility showed a non-significant relationship between borer incidence and moisture level. There was also not observed any marked differences in the moisture content of sugarcane varieties known to be resistant and susceptible to shoot borer [7]. During early stages of crop growth, resistant and susceptible varieties my not show much variations in the shoot moisture level [15].

**Spindle length and plant height:** At 45 DAP, wide variations ranging from 9.4 cm (Co 1148) to 13.2 cm (Co87263, CoH 99) were observed in spindle length of various genotypes. The shoots of least susceptible genotypes had an average spindle length of 13.05 cm. The moderately and highly susceptible genotypes with an average spindle length of 12.35 and 9.75 cm respectively showed significantly less spindle height than the least susceptible. Thus, significant inverse correlation became evident between spindle length and shoot borer incidence.

At 45 DAP, data showed that the shoot length of least susceptible cultivar CoJ 767 was highest (72.4 cm) followed by moderately susceptible CoH 2 (72.cm), CoH 15 (72.1) and CoH 99 (70.8 cm) and highly susceptible cultivars recorded the least (60.7cm). Thus, the data revealed a significant negative correlation between borer attack and total shoot height.

The average spindle length of least susceptible (17.9 cm) and moderately susceptible (17.5cm) entries at 60 DAP was higher than the highly susceptible genotypes (13.7cm). The susceptible variety Co1148 recorded the shortest spindle length (12.9 cm). The total shoot height of highly susceptible entries at 60 DAP was also significantly lower than the moderately and least susceptible ones (table 2 and 3). However, it fluctuated widely revealing irregular decreasing trend. While the spindle height showed a highly significant inverse correlation with borer incidence, the plant height did not show a clear cut correlation. Genotypes with longer spindles were shown to offer greater resistance to *C. infuscatellus* damage than those with shorter spindles. In an examination of sugarcane genotypes for shoot borer resistance the faster growing genotypes were found to contain lesser borer damage [13]. The early rapid growth of sugarcane during the period of susceptibility probably helps the crop to escape damage perhaps as consequences of host evasion [16]. This phenomenon has also been noticed in case of top borer, *Scirpophaga excerptalis*. Sugarcane genotypes with longer spindles suffered less damage to top borer, the larvae finding less time to reach the growing point [12, 17, 18, 9]. In sorghum also, varietal resistance to stem borer, *Chilo partellus* and shootfly, *Atherigona soccata* was found associated with rapid plant growth especially the tallness of spindles [19, 20, 21].

It must be pointed out that inverse relation between borer incidence and spindle length may not always be consistence or uniform under all condition, as varietal characters of this kind are sometimes subjected to variations under varying edaphic and climatic conditions and the impact of such variations may not always be similar on pest and host. Even so, this characters may be considered as one of those desirable ones, which in combination with other economical characters could profitably be used as indicator in selecting a suitable variety for shoot borer endemic regions. The relationship of borer incidence with spindle length has been found of a higher order than that with total shoot height as indicated by the value of coefficient of correlation. The total shoot height of susceptible entries, though was significantly lower than the moderately and least susceptible ones, yet it fluctuated widely among same group, showing irregular decreasing trend. This characteristic, therefore, may not be used as safe indication of the resistance or susceptibility of genotypes as spindle length.

**Chlorophyll:** The average chlorophyll ‘a’ content at 60 DAP was lower in genotypes with higher shoot borer incidence. The average chlorophyll ‘a’ content was estimated to be 60.29, 52.58 and 44.86 mg/gm in least, moderate and highly susceptible genotypes, respectively. Chlorophyll ‘b’ content was generally lower compared to chlorophyll ‘a’ content. The chlorophyll ‘b’ content also showed a steady decrease with borer susceptibility. In highly susceptible genotypes, the average chlorophyll content was recorded to be 27.7 mg/gm fresh weight as against 33.1 mg/gm observed in least susceptible (table 3). A consistent increase in total chlorophyll content was evident with in shoot borer resistance, being maximum in least susceptible entries and minimum in highly susceptible ones. In present study, significant positive correlation was observed between leaf chlorophyll and shoot borer resistance. Chlorophyll is considered an important factor which markedly influence both host selection and ovipositional behavior of several phytophagous insects and has been associated with resistance. Although scanty information is available on this aspect, yet [22] a negative correlation of leaf chlorophyll has been obtained with the susceptibility of sugarcane genotypes to *Scirpophaga excerptalis*. Similar observations have also been made earlier in sorghum genotypes susceptible to stem borer, *Chilo partellus* [23]. However, in case of sorghum shoot fly, *Atherigona soccata* the population density showed a positive association with both chlorophyll 'a' and 'b' content in sorghum cv. 5490 [24].

**Table1:** Morphological characters of sugarcane genotypes at 60 DAP in relation to *Chilo infuscatellus* incidence

| Cultivar/accession | Incidence (% dead hearts)* 1 | Leaf Colour 2 | Shape of canopy 3 | Light reflection (x10 lux) 4 | Leaf Length** (cm) 5 | Leaf Width (cm) 6 |
|---|---|---|---|---|---|---|
| Least Susceptible | | | | | | |
| Co 87263 | 8.10 (16.58) | Moderately Green | Erect | 1.24 | 60.20 (7.76) | 1.58 |
| CoS 767 | 11.30 (19.38) | Dark Green | Erect | 1.28 | 69.40 (8.33) | 1.83 |
| Mean | | | | 1.26 | 64.80 | 1.70 |
| Moderately Susceptible | | | | | | |
| CoH 2 | 18.40 (25.43) | Dark Green | Erect | 1.25 | 71.20 (8.44) | 2.35 |
| CoH 15 | 18.60 (25.55) | Moderately Green | Erect | 1.42 | 67.10 (8.19) | 1.75 |
| CoH 99 | 21.80 (27.83) | Moderately Green | Erect | 1.31 | 66.10 (8.19) | 1.98 |
| CoH 92 | 25.60 (30.37) | Moderately Green | Drooping | 1.41 | 54.75 (7.40) | 2.10 |
| Mean | | | | 1.34 | 64.78 | 2.04 |
| Highly Susceptible | | | | | | |
| CoH 108 | 34.30 (35.88) | Moderately Green | Drooping | 1.34 | 65.10 (8.07) | 2.12 |
| CoH 70 | 35.90 (36.82) | Light Green | Drooping | 1.32 | 60.50 (7.78) | 2.33 |
| CoJ 64 | 41.70 (40.22) | Light Green | Drooping | 1.46 | 58.00 (7.62) | 1.55 |
| Co 1148 | 47.00 (43.28) | Moderately Green | Drooping | 1.37 | 62.90 (7.93) | 1.82 |
| Mean | | | | 1.37 | 61.62 | 1.95 |
| SEm | 2.287 | | | 0.007 | | |
| CD(P=0.05) | 6.794 | | | 0.021 | | |
| r(P=0.05) | | | | 0.539 | -0.387 | 0.16 (NS) |

Figures in parentheses are angle transformed, ** Figures in parentheses are square root transformation NS= Non-significant

**Table2:** Physiological characters of sugarcane genotypes at 45 DAP in relation to *Chilo infuscatellus* incidence

| Cultivar/accession | Incidence (% dead hearts)* 1 | Leaf sheath hardness (kg/cm$^2$) 2 | Moisture (%)* 3 | Spindle length (cm)** 4 | Plant Height (cm)** 5 |
|---|---|---|---|---|---|
| Least Susceptible | | | | | |
| Co 87263 | 8.10 (16.58) | 2.84 | 63.65 (52.82) | 13.20 (3.63) | 59.85 (7.54) |
| CoS 767 | 11.30 (19.38) | 2.70 | 64.20 (53.23) | 12.90 (3.59) | 72.42 (8.51) |
| Mean | | 2.77 | 63.85 | 13.05 | 65.63 |
| Moderately Susceptible | | | | | |
| CoH 2 | 18.40 (25.43) | 2.69 | 65.70 (54.15) | 12.23 (3.49) | 72.30 (8.50) |
| CoH 15 | 18.60 (25.55) | 2.67 | 56.10 (48.51 | 13.03 (3.61) | 72.11 (8.50) |
| CoH 99 | 21.80 (27.83) | 2.71 | 65.80 (54.23 | 13.20 (3.63) | 70.75 (8.41) |
| CoH 92 | 25.60 (30.37) | 1.94 | 63.30 (52.70 | 10.97 (3.31) | 63.43 (7.96) |
| Mean | | 2.50 | 62.72 | 12.35 | 69.64 |
| Highly Susceptible | | | | | |
| CoH 108 | 34.30 (35.88) | 1.99 | 59.50 (50.48 | 10.67 (3.27) | 61.55 (7.95) |
| CoH 70 | 35.90 (36.82) | 1.87 | 67.90 (55.49 | 9.53 (3.90) | 67.97 (8.24) |
| CoJ 64 | 41.70 (40.22) | 2.11 | 60.40 (51.00 | 9.43 (3.07) | 57.05 (7.58) |
| Co 1148 | 47.00 (43.28) | 2.00 | 59.40 (50.40 | 9.40 (3.06) | 56.24 (7.51) |
| Mean | | 1.99 | 61.80 | 9.75 | 60.70 |
| SEm | 2.287 | 0.11 | 1.42 | 0.79 | 0.29 |
| CD(P=0.05) | 6.794 | 0.32 | 4.21 | 0.23 | 0.87 |
| r(P=0.05) | | -0.717 | -0.243 | -0.778 | -0.418 |

Figures in parentheses are angle transformed, ** Figures in parentheses are square root transformation

**Table 3:** Physiological characters of sugarcane genotypes at 60 DAP in relation to *Chilo infuscatellus* incidence

| Cultivar/accession | Incidence (% dead hearts)* | Leaf sheath hardness (kg/cm$^2$) | Moisture (%)* | Spindle length (cm)** | Plant Height (cm)** | Chlorophyll (mg/gm) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | chl. a | chl. b | Total |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Least Susceptible** | | | | | | | | |
| Co 87263 | 8.10 (16.58) | 3.27 | 72.00 (58.09) | 17.73 (4.21) | 67.82 (8.23) | 53.70 | 31.51 | 85.20 |
| CoS 767 | 11.30 (19.38) | 3.43 | 69.80 (56.65) | 18.03 (4.24) | 83.54 (9.14) | 66.90 | 34.61 | 101.71 |
| Mean | | 3.55 | 70.90 | 17.88 | 75.68 | 60.29 | 33.06 | 93.45 |
| **Moderately Susceptible** | | | | | | | | |
| CoH 2 | 18.40 (25.43) | 3.18 | 72.70 (58.50) | 19.30 4.39) | 88.56 (9.41) | 65.36 | 37.17 | 102.52 |
| CoH 15 | 18.60 (25.55) | 3.56 | 84.80 (53.62) | 17.80 (4.22) | 84.66 (9.20) | 48.12 | 25.13 | 73.25 |
| CoH 99 | 21.80 (27.83) | 3.16 | 71.70 (57.84) | 17.80 (4.22) | 83.57 (9.14) | 48.06 | 31.16 | 79.22 |
| CoH 92 | 25.60 (30.37) | 2.81 | 73.80 (59.24) | 15.23 (3.90) | 78.02 (8.83) | 48.81 | 27.21 | 76.01 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mean | | 3.17 | 70.75 | 17.53 | 83.70 | 52.58 | 30.16 | 82.75 |
| **Highly Susceptible** | | | | | | | | |
| CoH 108 | 34.30 (35.88) | 2.66 | 68.30 (55.75) | 14.80 (3.85) | 70.93 (8.42) | 38.81 | 21.47 | 68.28 |
| CoH 70 | 35.90 (36.82) | 2.15 | 72.00 (58.08) | 14.30 (3.78) | 77.77 (8.82) | 43.48 | 30.34 | 71.82 |
| CoJ 64 | 41.70 (40.22) | 2.71 | 68.80 (56.67) | 13.10 (3.62) | 68.35 (8.26) | 54.43 | 28.99 | 83.42 |
| Co 1148 | 47.00 (43.28) | 2.31 | 66.20 (54.44) | 12.93 (3.60) | 65.87 (8.10) | 42.73 | 30.18 | 72.74 |
| Mean | | 2.46 | 68.82 | 13.70 | 70.73 | 44.86 | 27.74 | 74.56 |
| SEm | 2.287 | 0.20 | 1.42 | 0.07 | 0.22 | 1.83 | 1.24 | 1.92 |
| CD(P=0.05) | 6.794 | 0.61 | 4.22 | 0.22 | 0,81 | 5.44 | 3.68 | 5.72 |
| r(P=0.05) | | -0.610 | -0.178 (NS) | -0.764 | -0.484 | -0.515 | -0.380 | -0.566 |

Figures in parentheses are angle transformed, ** Figures in parentheses are square root transformation NS= Non-significant

## Conclusion

It is inferred that sugarcane varieties with visibly pale looking, short, droopy and broad leaves, transmitting comparatively higher range of light with low leaf sheath hardness and less spindle length are more preferred for food than those with dark green, long, erect and narrow leaves plants having high leaf sheath hardness and more spindle length as the former may provide a better shelter or ovipositional site or protection to the borer species. Total chlorophyll content as such directly associated with resistance. These morphological characteristics in combination, therefore, could be used as an easy selection criterion in breeding for resistance to shoot borer.

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