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# Assessment of Response to Drought Stress of Chickpea (*Cicer arietinum* L.) Lines Under Rainfed Conditions

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**Abstract:** Totally sixty four chickpea lines were grown for assesment of response to drought stress in the stress and non-stress environments under rainfed conditions. The seed yield of the lines when grown under the non-stress condition increased at a rate of 53% over the in stress condition. The line, FLIP 92-154C, was determinated as the best tolerant line to drought stress environment under the field condition. Also, seed yield strongly correlated with biological yield, harvest index, mean productivity, tolerance to drought stress and drought susceptibility index in the stress environment.

## Yağmurla Beslenen Koşullar Altında Nohut (*Cicer arietinum* L.) Hatlarının Kuraklığa Tepkilerinin Belirlenmesi

**Özet:** Toplam altmışdört nohut hattı, kuraklık stresine tepkilerinin belirlenmesi amacıyla yağmurla beslenen koşullar altında kuraklık stresi ve kuraklık stresi olmayan çevrelerde yetiştirilmişlerdir. Kuraklık stresi olmayan koşullar altında yetiştirilen hatların dene verimleri kuraklık stresi olan kuşallardakilere göre %53 oranında artmıştır. FLIP 92-154C hattı, tarla koşullarında kuraklık stresi çevreleri için kuraklığa en tolerant hat olarak belirlenmiştir. Ayrıca, kuraklık stresi olan çevrelerde dane verimi ile biyolojik verim, hasat indeksi, ortalama verimlilik, kuraklık stresine tolerans ve kuraklığa duyarlılık indeksi arasında önemli ilişki bulunmuştur.

## Introduction

In Semi-Arid Tropics (SAT) and Mediterranean environments, especially in West Asia and North Africa (WANA), the major abiotic constraints are drought and high temperature stresses because spring crops, with the exceptions of faba bean (*Vicia faba* L.), pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medic.), are usually grown on poor soil and under low-input conditions. Chickpea (*Cicer arietinum* L.) is the only pulse crop which is sown in spring without irrigation in the Mediterranean basin (1, 2). The crop, in particular, is affected drought stress because of late sowings. Terminal drought stress is normally accompanied by increasing temperature towards maturity, often to levels, more than 30°C, those which may be affected to pod filling (3, 4). Although it is possible for the crop to avoid drought stress when sowing time is changed from spring to fall, but the breeding efforts for resistant to drought have been limited by contrast to cereals. Drought stress is the second important constraint of yield in chickpea after disease, while research efforts and success of breeding have a share of 10% and 5%, respectively (5). Breeding for resistance or tolerance to drought and high temperature stresses in chickpea is limited by the lack of adequate selection criteria for stress tolerance. Most breeding programs are based on visual scoring in the controlled or field conditions.

The objective of this paper was to evaluate of correlation among tolerance to drought stress, mean productivity and drought susceptibility index and yield and yield components as well as determining tolerance to stress of chickpea lines *via* drought susceptibility index under rainfed conditions.

## Materials and Methods

The present study was conducted under farmer's conditions. Sixty one chickpea lines from the International Center for Agricultural Research in the Dry Areas (ICARDA) and three checks, of which are an improved lines from ICARDA (FLIP 82-150C) and two checks from Turkey (ILC 482 and Ürkütlü native landrace) were grown between 1994-96, as winter (non stress environment)- and spring-sowings (stress environment) in the Mediterranean plateau. The lines were arbitrarly clustered in two groups accordance with line number (Table 2 and 3). The lines were planted as winter-sowing on 11 December 1994 and spring-sowing on 4 April 1996 in Ürkütlü, Burdur province (about 37°04' N, 30°12' E, 1014 m above sea level). Genotypes were

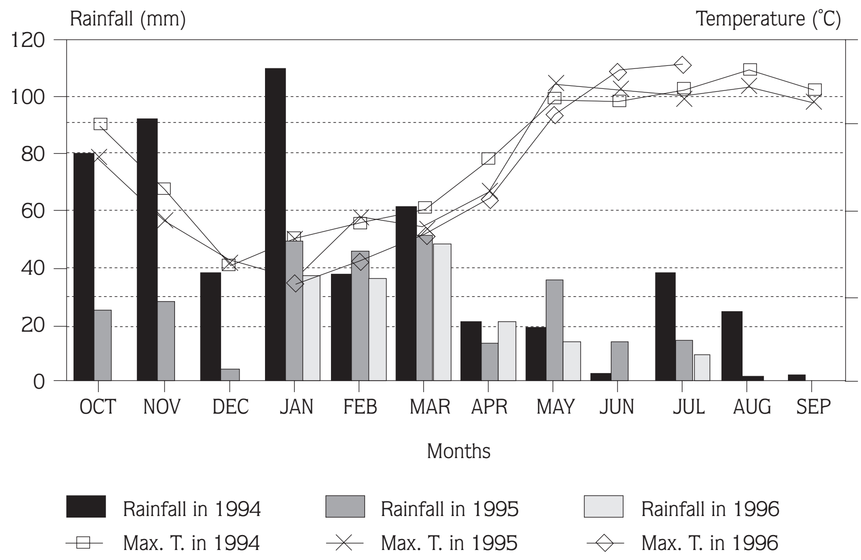


Figure 1. Monthly prencipitation and maximum temperatures between 1994-96 (6).

Table 1. Physical properties, macro and micro plant nutrients of the soil.

| Physical properties | | | Macro and micro plant nutrients | | | |
|---|---|---|---|---|---|---|
| pH | : | 8.050 | Available phosphorus | (ppm) | : | 8.198 |
| $CaCO_3$ (%) | : | 30.76 | Exchangeable potassium | (ppm) | : | 187 |
| Total soluble | | | Exchangeable calcium | (ppm) | : | 4648 |
| salt (%) | : | 0.002 | Exchangeable magnesium | (ppm) | : | 4648 |
| Sand (%) | : | 31.12 | Exchangeable sodium | (ppm) | : | 23 |
| Clay (%) | : | 26.88 | Available copper | (ppm) | : | 0.604 |
| Silt (%) | : | 42 | Available zinc | (ppm) | : | 0.184 |
| Texture | : | loam | Available iron | (ppm) | : | 4.62 |
| Total N (%) | : | 0.1064 | Available manganese | (ppm) | : | 2.324 |

grown in a randomized complete block design with two replications. The experimental plot, consisted of one row of 2 m length, 40 cm apart, were employed and forty seeds planted by hand per plot. The experimental lines were harvested by hand in June 1995 and July 1996, winter- and spring-sowings, respectively. The area harvested in each plot were 0.56 $m^2$. The experimental area was hand weeded. Fertilization was applied at a rate of 23 kg nitrogen and 60 kg phosphorus per hectare. The monthly rainfalls and maximum temperatures were given in Figure 1.

As it can be seen from Figure 1, precipitation is irragular. Also, high temperature raising to 36.3°C during reproductive phase of the growth in June, affect the crop drasticaly when planting time is shifted from March to the end of May in order to escape from *Ascochyta rabiei.*

A brief summary of the physical conditions of the soil was given in Table 1. Generally organic matter and macro plant nutrients was found at the low level.

The plot seed yield was recorded in grams in each line and then data was converted in kilograms to hectare basis. The biological yield was recorded in grams in each line. The harvest index was calculated in percent by using the following fomula: (Plot seed yield/Biological yield) x 100. The 100-seed weight was recorded in grams by multiplicating of means of the weight of twice sampled 50 kernels from each entry by 2 cofficient. The days to flower was recorded in days from planting time to the day on which at least 50% of plants in the plot had started to flowering. The plant height was measured in centimeters with the average height from hour randomly selected plants in the center of plot at the end of flowering.

The following equality suggested by Rosielle and Hamblin (7) was used for determination of tolerance to drought stress (TDS) of genotypes. Where $Y_3$ is TDS,

$$Y_3 = Y_2 - Y_1$$

$Y_1$ is the seed yield in the non-stress enviroonment (winter-sown) and $Y_2$ is in the stress environment (spring-sown). Mean productivity was calculated by using following formula:

$$Y_4 = (Y_1 + Y_2)/2$$

The mean productivity (MP) was defined as $Y_4$ (7) and rate of productivity (S/W) was arbitrated as $Y_5$.

$$Y_5 = (Y_2/Y_1)$$

Also, drought susceptibility index (DSI) was calculated with following equivalent used for cereals and applied by Fischer and Maurer (8), whereD is the rate of means as:

$$DSI = 1 - (Y_2/Y_2)/D$$

$$D = \frac{\text{Mean of all of} \quad \text{in } Y_2}{\text{Mean of all of genotypes in } Y}$$

Concequently, simple correlation matrix was obtained among the traits studied by using the MINITAB software program.

**Results and Discussion**

The seed yields of the lines in the non-stress environment clearly outyielded in the stress environment (Table 2 and 3) due to absence to drought stress. The yield of chickpea in the stress environment was restricted by limited moisture availability and traditional planting, i.e., spring sowing, resulding increased temperature during the reproductive stage of growth (1, 9, 10). Also, these results confirmed with Wery et. al. (4)'s findings. The seed yield of the lines in the non-stress environment was 1493 kg $ha^{-1}$ (Table 3) as average of the location, giving a 53% increase over the stress environment. Similar results were also reported by Hawtin and Singh (11).

On the basis of seed yield *per se*, lines, FLIP 91-45C, FLIP 92-110C and FLIP 92-154C gave a higher yield than the best check, ILC 482, and FLIP 90-111C the lowest in the non-stress environment. However, FLIP 92-163C, FLIP 92-191C and FLIP 92-154C gave the highest yields and FLIP 91-175C the lowest in the stress environment. The mean productivity was the highest in FLIP 92-154C, followed by FLIP 92-110C and FLIP 92-163C and FLIP 91-175C showed the lowest values. On the other hand, the tolerance to drought stress was the lowest in FLIP 90-8C, FLIP 92-167C and FLIP 90-111C lines, whereas FLIP 91-45C gave the highest value. The highest rate of productivity in the seed yield was observed in FLIP 90-8C and the lowest rate of productivity in ILC 482. Drought susceptibility index was ranged from -1. 166 to 0.025, in FLIP 90-8C and FLIP 92-65C, respectively.

The tolerance to drought stress, mean productivity, rate of productivity and drought susceptibility index was given in Table 2 and 3. In the non-stress environment, the higher yielding lines than the best check, ILC 482, had also high values for the mean productivity, e.g. FLIP 91-45C, FLIP 92-110C and FLIP 92-154C. High yield potential of the lines may be evaluated in the stress and non-stress environment. Also, high values for tolerance to drought stress of lines, (FLIP 91-45C, FLIP 92-169C and FLIP 92-102C) could be revealed as favorable for only adequate environment.

Sadiq et. al. (12), indicated that yield potential may be useful selection criterion in wheat under water-stress conditions. Therefore, high yielding lines in the non-stress environment may be advised to the non-stress environments for winter-sown if they tolerant to cold and resistant to ascochyta blight. On contrary, if seed yield of lines outyielded the best check in the stress environment and these lines had low value for the tolerance to drought stress, thus they could be considered as adopted to the stress environments.

The high yielding capacity and mean productivity of lines could be explained as tolerant to drought stress. Sadiq et. al. (12) reported that drought resistance may be present as an unidentified component of stability in genotype performance and provide an adequate assurance for farmers against environmental fluctuations

Table 2. The seed yield, mean productivity, tolerance to drought stress, rate of productivity and drought susceptibility index of chickpea lines.

| Lines | Yield in $Y_1$ | Yield in $Y_2$ | MP | TDS | S/W | DSI |
|---|---|---|---|---|---|---|
| FLIP 90-8C | 1000 | 964 | 982 | -36 | 0.964 | -1.166 |
| FLIP 90-111C | 911 | 661 | 786 | -250 | 0.726 | -0.632 |
| FLIP 91-15C | 1250 | 1054 | 1152 | -196 | 0.843 | -0.894 |
| FLIP 91-15C | 1464 | 714 | 1089 | -750 | 0.488 | -0.097 |
| FLIP 91-19C | 1107 | 518 | 813 | -589 | 0.468 | -0.052 |
| FLIP 91-45C | 2161 | 643 | 1402 | -1518 | 0.298 | 0.330 |
| FLIP 91-50C | 1536 | 1054 | 1295 | -482 | 0.686 | -0.542 |
| FLIP 91-58C | 1518 | 786 | 1152 | -732 | 0.518 | -0.164 |
| FLIP 91-59C | 1482 | 982 | 1232 | -500 | 0.663 | -0.490 |
| FLIP 91-63C | 1357 | 1000 | 1179 | -357 | 0.737 | -0.656 |
| FLIP 91-130C | 1411 | 661 | 1036 | -750 | 0.468 | -0.052 |
| FLIP 91-140C | 1517 | 732 | 1152 | -839 | 0.446 | -0.047 |
| FLIP 91-141C | 1429 | 804 | 1117 | -625 | 0.563 | -0.265 |
| FLIP 91-146C | 1375 | 804 | 1090 | -571 | 0.585 | -0.315 |
| FLIP 91-155C | 982 | 696 | 839 | -286 | 0.709 | -0.593 |
| FLIP 91-156C | 1375 | 732 | 1054 | -643 | 0.532 | -0.196 |
| FLIP 91-162C | 1286 | 804 | 1045 | -482 | 0.625 | -0.405 |
| FLIP 91-163C | 1268 | 661 | 965 | -607 | 0.521 | -0.171 |
| FLIP 91-169C | 1464 | 571 | 1009 | -875 | 0.395 | 0.112 |
| FLIP 91-175C | 964 | 482 | 723 | -482 | 0.500 | -0.124 |
| FLIP 91-183C | 1429 | 804 | 1117 | -625 | 0.563 | -0.265 |
| FLIP 91-189C | 1518 | 1054 | 1286 | -464 | 0.694 | -0.560 |
| FLIP 91-204C | 1517 | 804 | 1188 | -767 | 0.512 | -0.151 |
| FLIP 91-206C | 1589 | 714 | 1152 | -875 | 0.449 | -0.009 |
| FLIP 92-22C | 1196 | 768 | 982 | -482 | 0.642 | -0.443 |
| FLIP 92-25C | 1643 | 804 | 1224 | -839 | 0.489 | -0.099 |
| FLIP 92-27C | 1196 | 892 | 1044 | -304 | 0.746 | -0.676 |
| FLIP 92-40C | 1517 | 875 | 1223 | -696 | 0.557 | -0.252 |
| FLIP 92-48C | 1000 | 625 | 813 | -375 | 0.625 | -0.405 |
| FLIP 92-58C | 1232 | 786 | 1009 | -446 | 0.638 | -0.434 |
| FLIP 92-65C | 946 | 589 | 768 | -357 | 0.623 | 0.025 |
| Mean | 1340 | 775 | 1062 | -574 | 0.590 | -0.313 |
| *Checks* | | | | | | |
| FLIP 82-150C | 1617 | 1036 | 1327 | -581 | 0.641 | -0.441 |
| ILC 482 | 1786 | 446 | 1116 | -1340 | 0.250 | 0.438 |
| Ürkütlü | 1196 | 750 | 973 | -466 | 0.627 | -0.409 |
| Mean | 1533 | 744 | 1139 | -796 | 0.504 | -0.137 |

in water-stress areas. From above mentioned point of view, FLIP 92-154C was determined as the best drought tolerant line, followed by FLIP 92-110C and FLIP 92-163C.

The correlation matrix (Table 4), indicated strong and significant ($p< 0.01$) correlation of seed yield with biological yield (r=0.515 and 0.552) in the non-stress and stress environments, repectively. These results were agreement with the previously reported ones (13). A negative but non-significant correlation coefficent

Table 3. The seed yield, mean productivity, tolerance to drought stress, rate of productivity and drought susceptibility index of chickpea lines.

| Lines | Yield in $Y_1$ | Yield in $Y_2$ | MP | TDS | S/W | DSI |
|---|---|---|---|---|---|---|
| FLIP 92-98C | 1161 | 804 | 983 | -357 | 0.693 | -0.557 |
| FLIP 92-101C | 1214 | 643 | 929 | -571 | 0.530 | -0.191 |
| FLIP 92-102C | 1929 | 786 | 1358 | -1143 | 0.408 | 0.083 |
| FLIP 92-110C | 2036 | 929 | 1483 | -1107 | 0.456 | -0.025 |
| FLIP 92-111C | 1411 | 500 | 956 | -911 | 0.354 | 0.205 |
| FLIP 92-112C | 1500 | 518 | 1009 | -982 | 0.345 | 0.225 |
| FLIP 92-120C | 1714 | 679 | 1197 | -1035 | 0.396 | 0.110 |
| FLIP 92-122C | 1589 | 750 | 1170 | -839 | 0.472 | -0.061 |
| FLIP 92-123C | 1875 | 768 | 1372 | -1107 | 0.410 | 0.079 |
| FLIP 92-125C | 1393 | 732 | 1063 | -661 | 0.525 | -0.180 |
| FLIP 92-126C | 1732 | 982 | 1357 | -750 | 0.567 | -0.274 |
| FLIP 92-134C | 1339 | 518 | 929 | -821 | 0.387 | 0.130 |
| FLIP 92-135C | 1571 | 1000 | 1286 | -571 | 0.596 | -0.339 |
| FLIP 92-142C | 1643 | 946 | 1295 | -697 | 0.587 | -0.319 |
| FLIP 92-146C | 1554 | 714 | 1134 | -840 | 0.460 | -0.034 |
| FLIP 92-147C | 1679 | 1000 | 1340 | -679 | 0.596 | -0.339 |
| FLIP 92-154C | 1964 | 1071 | 1518 | -893 | 0.545 | -0.225 |
| FLIP 92-155C | 1875 | 857 | 1366 | -1018 | 0.457 | -0.027 |
| FLIP 92-162C | 1750 | 982 | 1366 | -768 | 0.561 | -0.261 |
| FLIP 92-163C | 1732 | 1214 | 1473 | -518 | 0.701 | -0.575 |
| FLIP 92-164C | 1786 | 1018 | 1402 | -768 | 0.570 | -0.281 |
| FLIP 92-165C | 1518 | 1036 | 1277 | -482 | 0.683 | -0.535 |
| FLIP 92-166C | 1464 | 1000 | 1232 | -464 | 0.683 | -0.535 |
| FLIP 92-167C | 1125 | 964 | 1045 | -161 | 0.857 | -0.926 |
| FLIP 92-169C | 1768 | 518 | 1143 | -1250 | 0.293 | 0.342 |
| FLIP 92-177C | 1268 | 857 | 1063 | -411 | 0.676 | -0.519 |
| FLIP 92-180C | 1589 | 714 | 1152 | -875 | 0.449 | -0.009 |
| FLIP 92-191C | 1518 | 1143 | 1331 | -375 | 0.753 | -0.692 |
| FLIP 92-195C | 1821 | 1000 | 1411 | -821 | 0.549 | -0.234 |
| FLIP 92-196C | 1714 | 857 | 1286 | -857 | 0.500 | -0.124 |
| Mean | 1607 | 850 | 1231 | -758 | 0.535 | -0.203 |
| Checks | | | | | | |
| FLIP 82-150C | 1617 | 1036 | 1327 | -581 | 0.641 | -0.441 |
| ILC 482 | 1786 | 446 | 1116 | -1340 | 0.250 | 0.438 |
| Ürkütlü | 1196 | 750 | 973 | -446 | 0.627 | -0.409 |
| Total Mean | 1493 | 790 | 1211 | -709 | 0.543 | -0.218 |

(r= -0.245) was obtained between harvest index and 100-seed weight in the non-stress environment.

Also, plant height was positively and significantly ($p< 0.05$) correlated with biological yield (r=0.307) in the non-stress environment, while this relationship was stronger (r=0.333) in the stress environment. Singh et. al. (14) also reported that seed yield are strongly positive correlated with biological yield, 100-seed weight and, to a less extent, with a plant height. In addition, Eser (15)

Table 4. Correlation matrix of mean productivity, tolerance to drought stress, rate of productivity, drought sensitivity index and other important traits in chickpea lines (N=64).

| | $SY_1$ | $SY_2$ | $BY_1$ | $BY_2$ | $HI_1$ | $HI_2$ | $SW_1$ | $SW_2$ | $PH_1$ | $PH_2$ | $F_1$ | $F_2$ | MP | TDS | S/W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SY_2$ | 0.275* | | | | | | | | | | | | | | |
| $BY_1$ | 0.628** | 0.011 | | | | | | | | | | | | | |
| $BY_2$ | 0.172 | 0.653** | 0.234 | | | | | | | | | | | | |
| $HI_1$ | 0.515** | 0.269* | -0.079 | -0.148 | | | | | | | | | | | |
| $HI_2$ | 0.178 | 0.552** | -0.213 | -0.257* | 0.506** | | | | | | | | | | |
| $SW_1$ | 0.155 | 0.014 | 0.402** | 0.338** | -0.245 | -0.305* | | | | | | | | | |
| $SW_2$ | 0.111 | 0.080 | 0.350** | 0.255* | -0.142 | -0.155 | 0.776** | | | | | | | | |
| $PH_1$ | 0.037 | -0.225 | 0.307* | 0.140 | -0.314* | -0.427** | 0.074 | 0.054 | | | | | | | |
| $PH_2$ | 0.070 | -0.084 | 0.339** | 0.333** | -0.329** | -0.458** | 0.137 | 0.102 | 0.980** | | | | | | |
| $F_1$ | -0.194 | -0.075 | 0.041 | 0.324* | -0.527** | -0.451** | 0.598** | 0.545** | 0.155 | 0.217 | | | | | |
| $F_2$ | -0.103 | 0.151 | -0.011 | 0.095 | -0.165 | 0.069 | 0.030 | 0.071 | 0.094 | 0.109 | -0.057 | | | | |
| MP | 0.885** | 0.691** | 0.477** | 0.445** | 0.517** | 0.401** | 0.123 | 0.122 | -0.081 | 0.012 | -0.212 | -0.004 | | | |
| TDS | -0.799** | 0.359** | -0.602 | 0.242 | -0.331** | 0.172 | -0.142 | 0.058 | -0.177 | 0.120 | 0.120 | 0.194 | -0.426** | | |
| S/W | -0.523** | 0.651** | -0.470** | 0.406** | -0.149 | 0.368** | -0.188 | -0.055 | -0.267* | -0.173 | 0.058 | 0.180 | -0.077 | 0.915** | |
| DSI | 0.523** | -0.651** | 0.470** | -0.406** | 0.149 | -0.368** | 0.118 | 0.055 | 0.267* | 0.173 | -0.058 | -0.180 | 0.077 | -0.915** | -1.0* |

| | | |
|---|---|---|
| SY: Seed yield | HI : Harvest index | F : Flowering |
| SY: Seed yield | SW: 100-seed weight | MP : Mean productivity |
| BY: Biological yield | SW: 100-seed weight | TDS: Tolerance to drougt stress |
| BY: Biolocical yield | PH: Plantheight | S/W: Rate of productivity |
| HI: Harvest inde0 | PH: Plant height | DSI : Drought susceptibility index |
| | F : Flowering | |

1: Non-stess and 2: Stress environments; Correlation significant 0.250 and 0.325 for 1 and 5% levels, respectively.

found that seed yield was correlated with pod number per plant.

The mean productivity was positively and significantly ($p < 0.01$) correlated with seed yield (r=0.885 and 0.691), biological yield (r=0.477 and 0.445), harvest index (r=0.517 and 401) and tolerance to drought index (r=-0.426) under drought stress and non-drought stress conditions, respectively. In the non-drought stress environment, tolerance to drought stress strongly and negatively ($p < 0.01$) correlated with seed yield (r=-0.799), biological yield (r=-0.602) and harvest index (r= -0.331), while it was positively correlated with seed yield (r=0.359) and biological yield (r=0.242) in the drought stress environment. When chickpea lines were planted in the non-drought stress condition, correlation of drought susceptibility index with seed yield (r=0.523), biological yield (r=0.470) and plant height (r=0.267) were found positive and significant ($p < 0.01$). Under drought stress environment, however, correlation coefficants for drought susceptibility index with the above mentioned traits were adversely obtained. Tolerance to drought stress strongly ($p < 0.01$) correlated with rate of productivity (r=0.915) and drought susceptibility index (r=-0.915).

Baker (15), introduced to the definition of stress tolerance and selection index. It was concluded that selection index in non-stress environments would be more effective than direct selection for productivity under stress whenever the correlation between the two types of environments exceeds the heritability of productivity under stress. There is the need to be incorporate drought tolerance mechanisms into germplasm with high yielding capacity to develop both high yielding and drought tolerant cultivars.


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