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# Thermal requirement of *Brassica* species under three dates of seeding

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ABSTRACT

A 3-year experiment was conducted to work out the thermal requirement of cultivars of *Brassica* species under different environments and to understand the behaviour of cultivars in utilizing the thermal energy. In general, the accumulated heat units and number of days for reaching various growth stages, vegetative, bolting and termination of flowering, on the main shoot decreased with successive delay in seeding. However, the days taken to attain these stages increased. The variation in accumulated heat units and number of days for reaching various growth stages in cultivars did not indicate any specific trend. Among cultivars, 'RH 30' mustard [*B. juncea* (L.) Czernj. & Cosson] and 'HNS 8' rape (*B. napus* L.) behaved in similar manner as they reached harvest in shortest duration and accumulated least heat units. Cultivar 'BC 2' Ethiopian mustard (*B. carinata* A. Braun) took maximum days for harvesting and in the process accumulated highest heat units in all treatments.

Any physiological and morphological development occurring in plants are markedly influenced by temperature and day length. Agronomic application of the temperature effects on plants is the concept of heat units or growing degree-days. The concept assumes that each plant has its own particular base or threshold temperature below which growth does not occur.

The concept of heat units have been applied to correlate the phenological development of different crops to predict maturity dates and yield (Keitzar and Singh, 1981; Swan *et al.* 1987). However, in case of rape (*Brassica napus* L.) and mustard [*B. juncea* (L.) Czernj. & Cosson] the relationship between heat units and growth stages does not appear to have been quantified. Hence a study was carried out to understand phenophase development in relation to environment variables in *Brassica* species.

## MATERIALS AND METHODS

The field experiment was carried out at Hisar (29° 10′N, 75° 46′E, altitude 215 m) during the winter seasons (October–April) of 1984–85 to 1986–87 on alkaline sandy-loam soil. The soil was poor in organic carbon and available nitrogen, medium in available phosphrus and rich in available potassium. The treatments consisted of 3 seeding dates [10 October ($S_1$), 25 October ($S_2$), 9 November ($S_3$) and 2 cultivars each of mustard ('RH 30' and 'Prakash'), rape ('HNS 8' and 'HNS 5') and Ethiopian mustard (*Brassica carinata* A. Braun). ('HC 2' and 'BC 2'). The treatments were replicated 3 times in split-plots of 5 m × 3.6 m of which 3 m × 6 m was used for

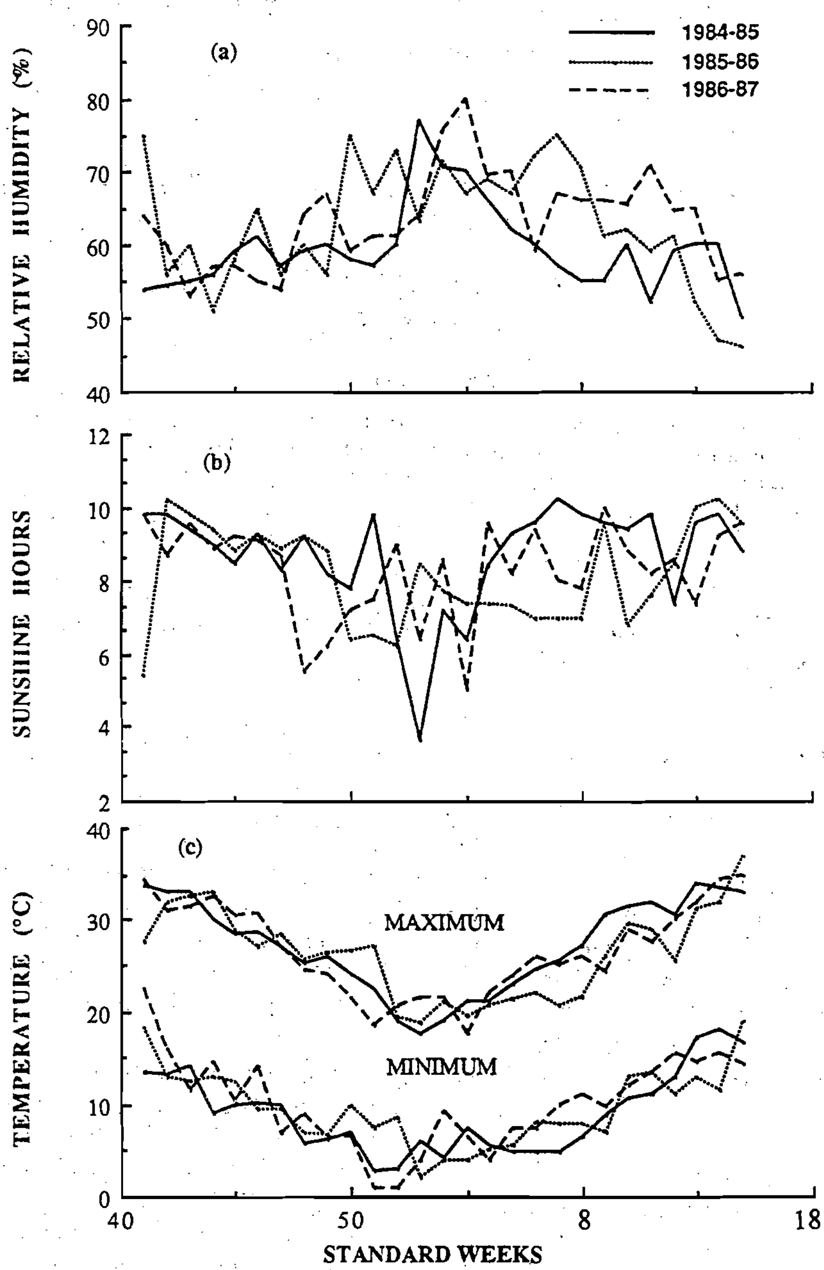


**Fig. 1.** Relative humidity, sunshine hours, minimum and maximum temperatures during 3 seasons

observations. Urea @ 80 kg N/ha, single superphosphate @ 30 kg $P_2O_5$/ha and zinc sulphate @ 25 kg/ha were applied as per recommended agronomic practice. The seed was drilled in rows 45 cm apart @ 5 kg/ha and plants within a row were thinned to 15 cm.

The number of days required for vegetative stage (GS1), bolting stage (GS2), termination of flowering on main shoot (GS3) and harvest of the crop (GS4) were recorded when 50% of plants in that particular plot reached the specified growth stages. The heat units (day °C) per day were calculated as the difference between the daily mean temperature and growth threshold temperature of 5°C, i.e. (maximum temperature + minimum temperature) 2–5. The cumulative heat units were recorded by summing the daily heat units from seeding to various growth stages. The daily meteorological data were recorded from the agrometeorological observatory, located 10 m away from the experimental field. The accumulated heat units for different growth stages were quantified for each species.

## RESULTS AND DISCUSSION

In general, weather was above normal during the crop season of 1984–85 and 1986–87, whereas it was slightly below normal in 1985–86. The gross minimum temperature values of –2°C (frost observed) and below were recorded on 6 days during 1984–85, 11 days during 1985–86 and 8 days during 1986–87. The weekly data on maximum and minimum temperatures, sunshine hours and relative humidity for 3 crop seasons are depicited in Fig. 1.

No clear relationship between the variations in heat units accumulated for occurrence of various growth stages (from seeding to specific growth stage) and difference in weather conditions prevailing in each of 3 crop seasons was observed (Tables 1, 2, 3; and Fig. 1). However, the accumulated heat units for reaching different growth stages from seeding decreased with delay in seeding in almost all cases, the differences between $S_1$ and $S_2$ were more pronounced than $S_2$ and $S_3$ seeding dates. The findings confirm the results of Patel and Mehta (1987). However, the late seeding increased the period (in days) to reach successive growth stages in all cases, except, 'BC 2' *B. carinata*. The possible reason being the less availability of thermal energy in late-seeded crop due to low temperature. Warrington and Kanemasu (1983) also reported similar results in maize. In general, the crop took less days to reach seed to seed as the seeding was delayed.

### Brassica juncea

The accumulated heat units for different growth stages in 'RH 30' were the highest in $S_1$, and the differences between the latter 2 seedings for accumulated heat units were only marginal (Table 1). The heat units required to attain harvest stage marginally differed within the years under all seeding dates, as evident from coefficient of variation values. The number of days from seeding to growth stages GS1, GS2 and GS3 were higher in $S_3$ than in $S_1$ and $S_2$ whereas the minimum days were taken to harvest with $S_3$ seeding followed by $S_2$ and $S_1$. The possible reason may be the low temperature encountered during early growth and high temperature towards maturity in the late-sown crop.

Among the 3 seeding dates, the accumulated heat units for reaching different growth stages in 'Parkash' were maximum in $S_1$ during the all years, differences between $S_2$ and $S_3$ being negligible (Table

**Table 1.** Heat units (day °C) and days required for various growth stage in *Brassica juncea* with different sowing dates

| Growth stage | Sowing date 1984–85 | | | | | | 1985–96 | | | | | | 1986–87 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV |
| | | | | | | | | | *'RH 30'* | | | | | | | | | |
| GS1 | 400 | 317 | 334 | 350 | 20.7 | 10.3 | 419 | 368 | 372 | 386 | 13.3 | 5.9 | 444 | 392 | 381 | 406 | 16.2 | 6.9 |
| | (22) | (21) | (26) | (23) | 1.2 | 9.4 | (24) | (23) | (29) | (25) | 1.5 | 10.5 | (23) | (23) | (27) | (24) | 1.1 | 7.9 |
| GS2 | 683 | 681 | 581 | 642 | 33 | 8.8 | 729 | 615 | 625 | 656 | 30 | 7.9 | 765 | 608 | 572 | 648 | 48.5 | 13 |
| | (42) | (44) | (54) | (47) | 3 | 11.1 | (45) | (43) | (57) | (48) | 3.6 | 12.9 | (43) | (41) | (55) | (46) | 3.6 | 13.4 |
| GS3 | 897 | 751 | 674 | 774 | 53 | 12 | 911 | 813 | 758 | 827 | 36.4 | 7.6 | 962 | 735 | 714 | 804 | 64.7 | 13.9 |
| | (60) | (59) | (71) | (63) | 3.1 | 8.6 | (61) | (62) | (76) | (66) | 3.9 | 10.4 | (60) | (58) | (72) | (63) | 3.6 | 9.8 |
| GS4 | 1,575 | 1,498 | 1,457 | 1,510 | 28.2 | 3.2 | 1,583 | 1,509 | 1,441 | 1,511 | 33.5 | 3.8 | 1,628 | 1,493 | 1,439 | 1,520 | 45.6 | 5.2 |
| | (140) | (138) | (136) | (138) | 0.9 | 1.2 | (141) | (139) | (137) | (139) | 0.9 | 1.2 | (137) | (135) | (132) | (135) | 1.2 | 1.5 |
| | | | | | | | | | *'Parkash'* | | | | | | | | | |
| GS1 | 530 | 464 | 415 | 470 | 27.1 | 10 | 591 | 514 | 412 | 506 | 42.2 | 14.5 | 621 | 519 | 448 | 529 | 41 | 13.4 |
| | (32) | (31) | (33) | (32) | 0.5 | 2.6 | (35) | (34) | (34) | (34) | 0.3 | 1.4 | (34) | (33) | (33) | (33) | 0.3 | 1.4 |
| GS2 | 947 | 758 | 674 | 793 | 65.8 | 14.4 | 944 | 824 | 721 | 830 | 52.5 | 11 | 994 | 739 | 697 | 810 | 75.6 | 16.2 |
| | (64) | (60) | (71) | (65) | 2.6 | 7 | (65) | (63) | (72) | (67) | 2.2 | 5.8 | (63) | (57) | (69) | (63) | 2.8 | 7.8 |
| GS3 | 1,101 | 889 | 858 | 949 | 62.4 | 11.4 | 1,139 | 971 | 903 | 1,004 | 57.2 | 9.9 | 1,119 | 915 | 889 | 974 | 59.5 | 10.6 |
| | (86) | (81) | (92) | (86) | 2.6 | 5.2 | (86) | (86) | (94) | (89) | 2.2 | 4.2 | (84) | (81) | (91) | (85) | 2.4 | 4.3 |
| GS4 | 1,731 | 1,654 | 1,659 | 1,681 | 20.2 | 2.1 | 1,686 | 1,630 | 1,636 | 1,651 | 14.4 | 1.5 | 1,750 | 1,589 | 1,614 | 1,651 | 41 | 4.3 |
| | (150) | (148) | (146) | (148) | 0.9 | 1.1 | (149) | (150) | (149) | (149) | 0.3 | 0.3 | (147) | (142) | (142) | (144) | 1.4 | 1.6 |

Details of growth stages and sowing dates are given under Materials and Methods
Figures in parentheses are number of days taken to attain the specific growth stage

**Table 2.** Heat units (day °C) and day required for various growth stages in *Brassica napus* with different sowing dates

| Growth stage | Sowing date | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984–85 | | | | | | 1985–86 | | | | | | 1986–87 | | | | | |
| | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV |
| | | | | | | | | | *'HNS 8'* | | | | | | | | | |
| GS1 | 414 | 346 | 356 | 372 | 17.3 | 8.1 | 419 | 368 | 385 | 390 | 12.2 | 5.4 | 440 | 376 | 381 | 399 | 16.8 | 7.3 |
| | (23) | (23) | (28) | (25) | 1.4 | 9.4 | (24) | (23) | (30) | (26) | 1.8 | 11.9 | (23) | (22) | (27) | (24) | 1.3 | 9.0 |
| GS2 | 716 | 587 | 565 | 623 | 38.5 | 10.6 | 714 | 628 | 635 | 659 | 22.5 | 5.9 | 754 | 608 | 587 | 650 | 42.9 | 11.4 |
| | (44) | (42) | (55) | (47) | 3.3 | 12.2 | (44) | (44) | (59) | (49) | 4.1 | 14.4 | (42) | (41) | (57) | (47) | 4.2 | 15.5 |
| GS3 | 899 | 751 | 657 | 769 | 57.6 | 13 | 916 | 824 | 729 | 823 | 44 | 9.3 | 962 | 753 | 714 | 810 | 62.9 | 1.3 |
| | (60) | (59) | (69) | (63) | 2.6 | 7.1 | (62) | (63) | (73) | (66) | 2.9 | 7.5 | (60) | (60) | (72) | (64) | 3.3 | 8.8 |
| GS4 | 1,575 | 1,516 | 1,494 | 1,528 | 19.8 | 2.2 | 1,583 | 1,472 | 1,454 | 1,503 | 32.9 | 3.8 | 1,641 | 1,444 | 1,439 | 1,508 | 54.3 | 6.2 |
| | (14) | (139) | (138) | (139) | 0.5 | 0.6 | (141) | (137) | (138) | (139) | 1 | 1.2 | (138) | (132) | (132) | (134) | 1.6 | 2.1 |
| | | | | | | | | | *'HNS 5'* | | | | | | | | | |
| GS1 | 697 | 648 | 674 | 673 | 11.6 | 3 | 729 | 709 | 721 | 720 | 4.7 | 1.1 | 765 | 668 | 676 | 703 | 25.4 | 6.3 |
| | (42) | (52) | (71) | (55) | 6.9 | 21.9 | (45) | (52) | (72) | (56) | 6.6 | 20.3 | (43) | (46) | (66) | (52) | 5.9 | 19.6 |
| GS2 | 961 | 878 | 892 | 910 | 21 | 4 | 998 | 937 | 940 | 958 | 16.6 | 2.9 | 1038 | 883 | 900 | 940 | 40.1 | 7.4 |
| | (65) | (79) | (96) | (80) | 7.3 | 15.8 | (69) | (81) | (98) | (83) | 6.9 | 14.3 | (67) | (78) | (92) | (79) | 5.9 | 12.9 |
| GS3 | 1,123 | 1,051 | 1,119 | 1,098 | 19.1 | 3 | 1,164 | 1,091 | 1,135 | 1,130 | 17.3 | 2.7 | 1,156 | 1,028 | 1,120 | 1,101 | 31.1 | 4.9 |
| | (89) | (101) | (115) | (102) | 6.1 | 10.4 | (91) | (102) | (117) | (103) | 6.2 | 10.3 | (89) | (95) | (110) | (98) | 5.1 | 9.0 |
| GS4 | 1,856 | 1,811 | 1,780 | 1,816 | 18 | 1.72 | 1,848 | 1,765 | 1,750 | 1,788 | 24.8 | 2.2 | 1,883 | 1,731 | 1,653 | 1,756 | 55.1 | 5.4 |
| | (58) | (158) | (152) | (155) | 1.4 | 1.6 | (159) | (166) | (154) | (156) | 1.2 | 1.3 | (156) | (150) | (144) | (150) | 2.8 | 3.3 |

Details of growth stages and sowing dates are given under Materials and Methods
Figures in parentheses are number of days taken to attain the specific growth stage

**Table 3.** Heat units (day °C) and days required for various growth stages in *Brassica carinata* with different sowing dates

| Growth stage | Sowing date 1984–85 | | | | | | 1985–86 | | | | | | 1986–87 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV | $S_1$ | $S_2$ | $S_3$ | Mean | SE | CV |
| | | | | | | | | | *'HC 2'* | | | | | | | | | |
| GS1 | 781 | 723 | 635 | 713 | 34.4 | 8.4 | 821 | 744 | 681 | 749 | 33.0 | 7.6 | 841 | 720 | 697 | 753 | 36.0 | 8.4 |
| | (51) | (55) | (66) | (57) | 3.7 | 11.1 | (53) | (55) | (66) | (58) | 3.3 | 9.9 | (49) | (52) | (69) | (57) | 5.1 | 15.4 |
| GS2 | 947 | 870 | 876 | 898 | 20.2 | 3.9 | 1,015 | 937 | 892 | 948 | 29.3 | 5.4 | 1,045 | 851 | 923 | 940 | 46.2 | 8.5 |
| | (64) | (78) | (94) | (79) | 7.1 | 15.5 | (71) | (81) | (93) | (82) | 5.2 | 10.9 | (69) | (75) | (94) | (79) | 6.2 | 13.5 |
| GS3 | 1,123 | 1,073 | 1,089 | 1,095 | 12.1 | 1.9 | 1,164 | 1,119 | 1,086 | 1,123 | 18.5 | 2.8 | 1,157 | 1,026 | 1,139 | 1,107 | 33.5 | 5.2 |
| | (89) | (103) | (113) | (102) | 5.7 | 9.6 | (91) | (105) | (113) | (103) | 5.2 | 8.8 | (89) | (97) | (112) | (99) | 5.5 | 9.6 |
| GS4 | 1,988 | 2,087 | 1,955 | 2,010 | 32.3 | 2.8 | 1,961 | 2,069 | 1,880 | 1,970 | 44.7 | 3.9 | 2,035 | 2,031 | 1,837 | 1,968 | 53.3 | 4.7 |
| | (66) | (170) | (161) | (166) | 2.1 | 2.2 | (167) | (172) | (160) | (166) | 2.8 | 2.9 | (165) | (161) | (153) | (160) | 2.9 | 3.1 |
| | | | | | | | | | *'BC 2'* | | | | | | | | | |
| GS1 | 1,035 | 918 | 701 | 885 | 79.9 | 15.6 | 1,102 | 971 | 763 | 945 | 80.6 | 14.8 | 1,080 | 904 | 749 | 911 | 78 | 14.8 |
| | (75) | (85) | (74) | (78) | 2.9 | 6.4 | (80) | (86) | (77) | (81) | 2.2 | 4.6 | (77) | (80) | (77) | (78) | 0.8 | 1.8 |
| GS2 | 1,205 | 1,036 | 920 | 1,054 | 67.5 | 11.1 | 1,254 | 1,083 | 991 | 1,109 | 62.9 | 9.8 | 1,257 | 1,049 | 993 | 1,100 | 65.6 | 10.3 |
| | (101) | (99) | (99) | (100) | 0.5 | 0.9 | (104) | (101) | (103) | (103) | 0.7 | 1.2 | (100) | (99) | (100) | (100) | 0.3 | 0.5 |
| GS3 | 1,484 | 1,260 | 1,150 | 1,298 | 80.2 | 10.7 | 1,474 | 1,310 | 1,197 | 1,327 | 65.5 | 8.6 | 1,504 | 1,293 | 1,222 | 1,340 | 69.2 | 8.9 |
| | (132) | (122) | (117) | (124) | 3.6 | 5.0 | (130) | (125) | (121) | (125) | 2.1 | 2.9 | (127) | (120) | (118) | (122) | 2.2 | 3.2 |
| GS4 | 2,070 | 2,107 | 1,979 | 2,052 | 31.0 | 2.6 | 2,008 | 2,115 | 1,924 | 2,016 | 45.1 | 3.9 | 2,086 | 2,053 | 1,872 | 2,004 | 54.3 | 4.7 |
| | (170) | (171) | (162) | (168) | 2.3 | 1.4 | (170) | (174) | (162) | (169) | 2.9 | 2.9 | (168) | (167) | (155) | (163) | 3.4 | 3.6 |

Details of growth stages and sowing dates are given under Materials and Methods
Figures in parentheses are number of days taken to attain the specific growth stage

1). The days taken to attain GS1 did not differ much with seeding dates. However, the days taken to reach GS2 and GS3 from seeding were more in S3 than the 2 seeding dates. The total crop duration decreased slightly with successive delay in seeding, as the crop finished its life-cycle earlier in late sowing. These results are in close agreement with Patel and Mehta (1987). Among the years, the crop duration was shortest during 1986–87.

Brassica napus

The phenological behaviour of 'HNS 8' was similar to the 'RH 30' except smaller differences of heat units and duration. The cultivar accumulated maximum heat units in $S_1$ treatment (Table 2).

The maximum heat units at harvest were accumulated in $S_1$ seeding in 'HNS 5' (Table 2). The number of days taken to reach various growth stages increased with delay in seeding. The crop seeded on $S_3$ date took minimum days (150 days) to reach seed to seed and it was maximum in $S_1$ (158 days averaged over 3 crop seasons). The relative increase in number of days taken to attain growth stages GS1, GS2 and GS3 was higher when we compare the differences between $S_3$ and $S_2$ with $S_2$ and $S_1$. The possible reason may be the lower temperatures in $S_3$ than in $S_2$.

Brassica carinata

No specific trend was observed for accumulated heat units and number of days taken to maturity in the cultivars of *B. carinata* (Table 3). However, amongst the 3 species, *B. carinata* took maximum days to reach maturity and in the process consumed the maximum het units (Tables 1, 2, 3). The possible explanation for higher heat-unit accumulation and more days taken to initiate flowering (GS2) in this species may be sought in the growth habit of this species under Hisar conditions where the bolting phase got initiated only towards the early February, implying thereby that this species have a specific heat requirement for initiation of reproductive phase.

In 'HC 2', the requirement of heat units for attaining successive growth stage decreased with delayed seeding accompanied by an increase in number of days taken to reach these growth stages, except maturity. The total crop duration was shortest in $S_3$ seeding but the accumulated heat units to reach harvest were maximum in $S_2$, followed by $S_1$ and $S_3$. Almost similar trend was observed in 'BC 2'. However 'BC 2' was considerably late in attaining successive growth stages compared with 'HC 2', particularly till GS3 stage and the phenomenon was more pronouced in $S_1$ and $S_2$ seedings.

There were considerable differences in accumulated heat units and days taken to reach different growth stages among species and cultivars. This is in consistent with findings of Kasa and Kondra (1986). The cultivars 'RH 30' and 'HNS 8' had shortest crop duration among 6 cultivars. These cultivars were harvested 132 days after seeding ($S_3$), accumulating 113 day °C in the third year. However, in second year the crop 'BC 2' sown on $S_2$ matured very late taking 174 days to harvest and in process accumulated 2115 day °C, which was maximum for any cultivar.

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