# Drought Vulnerability of Rainfed Crops in Semiarid Tropics in India:

## New Methods of Determining Rainfall Variability

**U. S. Victor, N. N. Srivastava, and P. Vijay Kumar**
**Central Research Institute for Dryland Agriculture**
**Santoshnagar, Hyderabad, India**

In dryland areas of India, rainfall is the main source of water for raising crops. For these areas, the greatest problem is not water shortage per se, but rather the tremendous variability in rainfall from year to year and season to season. In planning for the coming season, we currently have little or no ability to predict the date of the onset of rains or their amount, distribution, or duration. However, uncertainty about rainfall is lessened when information is available concerning the possible variability and frequencies of historical occurrences of rainfall. This information can be obtained by coupling water use to water production functions that enable estimates of associated crop yields and economic returns (Stewart and Hagan, 1973; and Doorenbos and Kassam, 1979). Therefore, in the present study, a simple water balance model developed by Frere and Popov (1979) was used to estimate crop water use; when coupled with water production functions, it explains yield behavior of the following crops (with respect to different dates of commencement of the rainy season): sorghum (*Sorghum bicolor L. Moench*), pearl millet (*Pinnisatum americanum L. Leek*), sunflower (*Helianthus annus L.*), castor (*Ricinus communis L.*), and pigeon pea (*Cajanus cajan L. Millisp.*) These crops are grown in Hyderabad under high management and rainfed conditions.

### Study Area and Materials

Hyderabad (17° 27' N, 78° 28' E), situated in a semiarid tract of southern India, receives an annual rainfall of 767 mm, compared to potential evapotranspiration of 1,754 mm. The rainfall occurs mostly during the southwest monsoon season, from June to September, and post-monsoon rains are not uncommon.

The soils of the experimental site are red shallow loamy sands. The depth of top soil varies from 5 to 30 cm. Moisture storage in the profile is only 10% by volume.

Weekly water balances were worked out for the period 1901–93 using the water balance model of Frere and Popov (1979) by assuming that the crops are sown when 20 mm of rainfall has been received after May 20. The available water-holding capacity of the soil in the root zone is 50 mm for sorghum, pearl millet, and sunflower, and 100 mm for castor and pigeon pea. The crop coefficient values suggested by Doorenbos and Pruitt (1977) were adopted. The lengths of the growing season for sorghum, pearl millet, pigeon pea, castor, and sunflower are 13, 13, 21, 21, and 14 weeks, respectively. Crop water use was evaluated for each growing season for each crop for the period 1901–93.

### Yield Patterns

Water production functions were developed using crop water use data for each study crop. The correlation coefficients between crop water use and yields of crops are in the range of 0.95–0.99. Yearly crop yields were estimated using the water productions for the period 1901–93. The individual years were grouped according to the dates of commencement of the rainy season. Frequency of occurrence of different dates of commencement of the rainy season are given in Table 1. Probabilities for different production levels of crops in relation to different dates of commencement of the rainy season were also worked out; these are given in Table 2, along with extremes of crop water use and maximum yields. Table 2 shows a gradual decline in

| Dates of Commencement of Rainy Season | Frequency of Occurrence |
|---|---|
| May 21–June 3 | 29 |
| June 4–July 17 | 36 |
| June 18–July 1 | 24 |
| July 2 and beyond | 4 |

**Table 1. Frequency of occurrence of commencement of rainy season at Hyderabad (data base: 1901–93).**

| Dates of Commencement of Rainy Season | Test Crop | Crop Water Use (mm) High | Low | Mean | Maximum Possible Yield (t/ha) | Probabilities for Reaching ≥75% max. yield | ≥ 50% max. yield | ≥25% max. yield |
|---|---|---|---|---|---|---|---|---|
| May 21–June 3 | Sorghum | 363 | 207 | 289 | 6.1 | 41 | 83 | 100 |
| June 4–June 17 | (CSH–6) | 335 | 233 | 297 | 5.4 | 56 | 92 | 100 |
| June 18–July 1 | | 314 | 174 | 277 | 4.8 | 38 | 79 | 96 |
| July 2–on | | 299 | 236 | 262 | 4.4 | 0 | 75 | 100 |
| May 21–June 3 | Pearl | 363 | 215 | 288 | 5.1 | 34 | 69 | 97 |
| June 4–June 17 | millet | 335 | 233 | 296 | 4.4 | 50 | 83 | 100 |
| June 18–July 1 | (BJ–104) | 314 | 174 | 276 | 3.9 | 21 | 67 | 92 |
| July 2–on | | 299 | 250 | 261 | 3.5 | 0 | 50 | 100 |
| May 21–June 3 | Sunflower | 362 | 208 | 304 | 1.00 | 86 | 100 | 100 |
| June 4–June 17 | (EC–68415) | 344 | 244 | 309 | 0.93 | 83 | 100 | 100 |
| June 18–July 1 | | 322 | 200 | 292 | 0.87 | 71 | 100 | 100 |
| July 2–on | | 293 | 260 | 271 | 0.84 | 75 | 100 | 100 |
| May 21–June 3 | Castor | 493 | 349 | 448 | 2.5 | 62 | 86 | 100 |
| June 4–June 17 | (Aruna) | 469 | 354 | 440 | 2.3 | 64 | 89 | 100 |
| June 18–July 1 | | 448 | 330 | 411 | 2.0 | 29 | 71 | 96 |
| July 2–on | | 422 | 287 | 364 | 1.8 | 0 | 50 | 100 |
| May 21–June 3 | Pigeon Pea | 491 | 330 | 441 | 2.3 | 69 | 97 | 100 |
| June 4–June 17 | (HY2) | 466 | 370 | 440 | 2.1 | 72 | 100 | 100 |
| June 18–July 1 | | 445 | 330 | 415 | 1.9 | 50 | 96 | 100 |
| July 2–on | | 419 | 289 | 371 | 1.7 | 0 | 75 | 100 |

**Table 2. Probabilities of different production levels of crops, extremes of crop water use, and maximum yields with respect to different dates of commencement of the rainy season at Hyderabad (data base: 1901–93).**

*This article appeared in the October 1994 issue of* ***Drought Network News.***

the maximum yield with the delay in the commencement of the rainy season in the case of all crops. The mean crop water use decreases with the delay in the commencement of the rainy season for the long-duration crops of castor and pigeon pea. However, in the case of short-duration crops (sorghum, pearl millet, and sunflower), the average crop water use is comparatively higher during years with a normal commencement of the rainy season (June 4–17). Reduction in crop water use is likely during years when the commencement of the rainy season is earlier or later than the normal commencement.

Table 2 also shows that the chance of reaching 75% of maximum yield is greater during years with normal commencement of the rainy season. However, if the crops are sown after July 1, the chance of reaching 75% of the maximum yield is zero, except for sunflower. Although the average rainfall for short-duration (513 mm) and long-duration (639 mm) crops is much more than the actual water requirements of the crops, the chances of reaching even 75% of the potential yield vary from 21% to 56% for the cereal crops of sorghum and pearl millet and 29% to 72% for the long-duration crops of castor and pigeon pea, depending on the date of commencement of the rainy season. Therefore, appropriate in situ rain water management practices have to be evolved to cope with mild to moderate droughts during the cropping season.

## Summary

Analysis of available weather records—primarily rainfall and evapotranspiration—coupled with crop yield data permits evaluation of (1) the suitability of a given crop for production at the planting site and (2) the earliest and latest acceptable dates of the onset of the rains for growing the study crop. The method can also be used to predict the likely yields of the crops two months before harvest. This type of method holds great promise for use on an operational basis in dry farming areas.

## References

Doorenbos, J.; and W. O. Pruitt. 1977. Guidelines for predicting crop water requirements. *FAO Irrigation and Drainage Paper* No. 24, pp. 35–41.

Doorenbos, J.; and A. H. Kassam. 1979. Yield response to water. *FAO Irrigation and Drainage Paper* No. 33.

Frere, M.; and G. F. Popov. 1979. Agrometeorological crop monitoring and forecasting. *FAO Plant Production and Protection Paper* No. 17, p. 64.

Stewart, J. I.; and R. M. Hagan. 1973. Functions to predict effects of crop water deficits. *Journal of Irrigation and Drainage Division, ASCE*—Proceedings Paper 10229, 99; pp. 421–39.