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Droughts and Dew Bean Productivity in Northwestern Arid Rajasthan, India

Pratap Narain
Central Arid Zone Research Institute, Jodhpur 342 003, India

R. S. Singh
Central Arid Zone Research Institute, Jodhpur 342 003, India

D. Kumar
Central Arid Zone Research Institute, Jodhpur 342 003, India

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Arid ecosystems constitute an important part of the world's dry climates. The Indian arid zone is characterized by a harsh and fragile system, which influences the productivity (both quantitative and qualitative) and socioeconomic status of the inhabitants. The study discussed in this article was conducted in the Bikaner region, which is one of the most drought-prone districts of Rajasthan (Figure 1). Annual rainfall in the district is 268 mm, of which 85% occurs during the southwest summer monsoon (July–September). The region is known to experience extreme variations in diurnal and seasonal temperatures and high wind velocity, particularly during summers, associated with high evaporative atmospheric demands. Skies tend to be clear (cloud free) in these regions throughout most of the year. Soils of the Bikaner region are characteristically light and sandy, with a high infiltration rate and <100 mm field capacity, and are prone to wind erosion. Cultivation of crops is a challenging task under prevailing hostile atmospheric situations and soil limitations.

Agriculture is predominantly rainfed in this region. Among the arable crops, dew bean (Vigna aconitifolia [Jacq.] Marechal), commonly known as moth bean, is rated as one of the most adapted arid legumes in the region, because of its tolerance to drought and heat (Kumar, 1996). It matures in 70–75 days, matching the length of the rainy season in the region, and it fits well in harsh climates with rainfall of 200–250 mm, even when rainfall distribution is erratic. Hence, 25% of the moth bean area (269,971 ha) of Rajasthan state is confined to the arid district of Bikaner. The moth bean crop is grown as a "neglected" crop in this region, left up to the mercy of farmers. As such, no crop improvement programs have been adopted for this crop. It forms an important protein supplement in vegetarian diets and is used for several confectionary items throughout the country.

The crop is cultivated alone and in various cropping systems on plains and sand dunes. Its water requirement is very low. On average, the evapotranspiration rate is 1.8–2.2 mm day^{-1} during emergence and early growth stages of the crop, with a maximum of 4.8 mm day^{-1} during flowering and pod formation stages (Singh et al., 2000). It is, however, susceptible to yellow mosaic virus disease. In the Bikaner region, insufficient and erratic rains, coupled with exceptionally longer dry spells (20–40 days), cause poor emergence and seedling mortality, which in turn result in patchy and poor plant stand. This study focuses on the relationship between interannual variability in crop productivity and rainfall, using drought frequencies and their intensities to discuss crop performance over the last 30 years (1968–97).

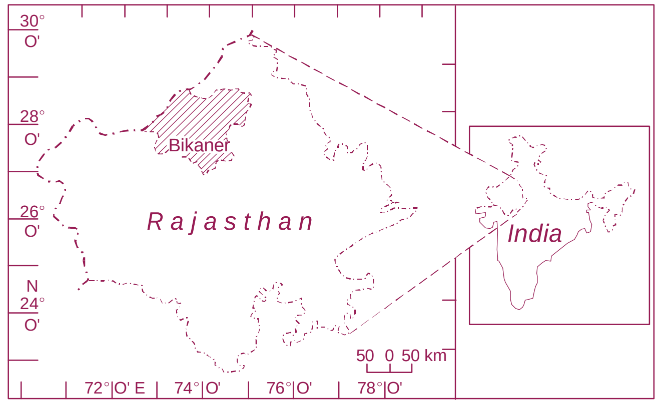

Figure 1. Location of study area.

Interannual Variability in Moth Bean Production

Variation in net sown area (hectares) and total production (tons) of moth bean over the 30 years in this study is shown in Figure 2. Normal production of moth beans was 39,643 tons against the long-term mean area of 269,971 ha. Variability in crop production (90%) was many times higher than the variability in the net sown area (16%). Slight to negligible reduction in crop area in drought years shows farmers' preferences for this crop. Long-term linear trends also indicate that there was no significant change in net sown area and total production over the reported periods, excepting 1975–78. Thus, stagnation in area and production of this important arid legume over the last 30 years is a matter of great concern, considering its potential in arid ecosystems. It is grown as a second-choice crop by small and marginal farmers only, which is not a healthy trend.

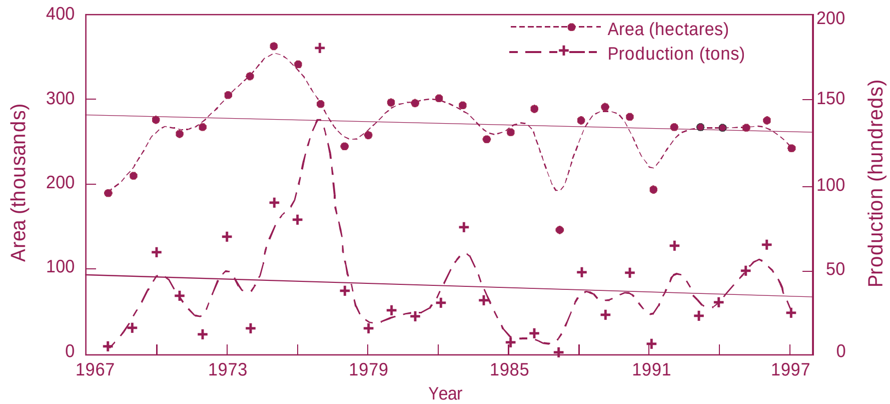

Figure 2. Interannual variability and trends in moth bean area and production from Bikaner region of Indian desert (1968–97).

Rainfall and Crop Yields

Year-to-year fluctuations in rainfall (July–September) and crop yields (kg ha^{-1}) are shown in Figure 3. Average crop yield was 139.1 kg ha^{-1} and average rainfall during the cropping season (July–September) was 191 mm. The maximum crop yield (613 kg ha^{-1}) occurred in 1977, which had good monsoon rains. The worst crop yield year was 1987, which experienced severe drought. The long-term trend in crop productivity data emphatically indicates that there was no change (increasing or decreasing) in the productivity pattern of the moth bean crop in this dry region. There are few visible technological impacts on the productivity of this legume in the Bikaner region. A positive sign, however, is the crop's responsiveness to variations in rainfall. Higher yields of the moth bean during 1975–78 are explained by adequate, well-distributed rainfall. Thus, moth bean has tremendous potential in arid regions of northwestern Rajasthan, and rainfall during July–September plays an important role in determining its yield. The linear regression between the crop yield (Y) and rainfall (X) during July–September is given below.

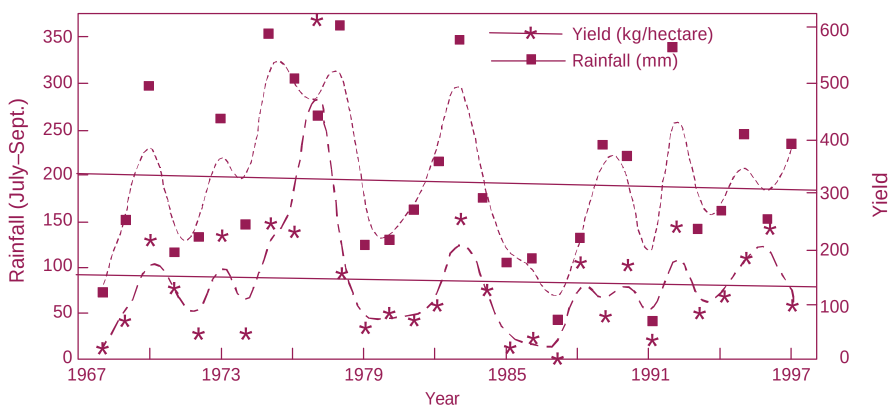

Figure 3. Interseasonal fluctuations and trends in rainfall and moth bean yield from Bikaner district of Indian desert (1968–97).

No drought years	1975, 1977, 1978, 1983, 1992, 1995, and 1996 (7 years)
Mild drought years	1970, 1973, 1976, 1980, 1982, and 1997 (6 years)
Moderate drought years	1969, 1971, 1984, 1988, 1989, 1990, and 1994 (7 years)
Severe drought years	1968, 1972, 1974, 1979, 1981, 1985, 1986, 1987, 1991, and 1993 (10 years)

Table 1. Intensity and frequency of agricultural drought over Bikaner district, 1968–97.

Drought Intensity	Frequency	Average Area (ha)	Percent Reduction	Average Production (tons)	Percent Reduction (kg/ha)	Average Yield	Percent Reduction
No drought	7	285,148	—	79,307	—	274.3	—
Mild drought	6	294,267	—	47,660	40	159.0	42
Moderate drought	7	262,449	8	33,145	58	124.6	55
Severe drought	10	250,035	12	11,616	85	42.6	85

Table 2. Impact of agricultural drought on productivity of moth bean crop in Bikaner district, 1968-97.

$Y = 0.81 \times X - 14.8$; $r = 0.6245^{**}$

** significant at $P = 0.01$ with $R^2 = 0.39$ and d.f. = 29

The crop yields (Y) have a better association ($r = 0.8116$) with rainfall (X) during the first fortnight of September, which normally coincides with the reproductive (pod filling) stage of the crop. The linear regression is shown below.

$Y = 3.05 \times X + 78.3$; $r = 0.8116^{**}$

**significant at $P = 0.01$ with $R^2 = 0.66$ and d.f. = 29

Agricultural Droughts and Crop Productivity

The climatic water balance was determined on a weekly basis using precipitation and potential evapotranspiration data for each cropping season (July–September) over the 30-year period 1968–97, as adapted by Thornthwaite and Mather (1955). The ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET) was computed for each week/ growth stage of the crop to determine the intensity of drought experienced by the crop in the region (Sastri et al., 1982). The moth bean crop experienced severe agricultural droughts during 10 years, moderate droughts during 7 years, mild droughts during 6 years, and no droughts during 7 years in the region (Table 1). This also indicates that droughts are frequent and common phenomena in the region. In general, the crop suffers severe/moderate agricultural droughts in every alternate year, which adversely affects crop production.

It is worth mentioning that during severe drought situations, the cropped area was reduced insignificantly (12%) while the productivity of this arid legume was reduced about 85%. Moderate drought reduced yields by about 55%, but the cropped area was reduced by only 8% (Table 2). These figures reveal that even under moderate to severe droughts, farmers in the Bikaner region are committed to planting this drought-hardy arid legume. Lesser fluctuations in the cropped area during drought years confirm the preference of farmers for this crop and the high degree of adaptation of the moth bean to the harsh situations (drought, heat, and soil movement) in Bikaner. Compared to the total failure of other crops like pearl millet, reductions of 85% in severe drought years and only 55% in moderate drought years reveal the drought hardiness of moth beans. Increasing drought tolerance and production potential of drought-hardy legumes is necessary for bringing sustainability to this agro-ecosystem of a hot and hostile arid district of the Indian subcontinent.

Strategies for the Future

Agricultural scientists/planners should address the following issues:

- Breeding for biotic and abiotic stresses to enhance production potential.
- Development of early maturing strains of 60–65 days.
- Developing suitable innoculum for N-fixation.
- Adoption of improved agronomic practices.
- Adoption of promotional policies for increasing the area planted to moth beans, raising the status of the crop from neglect to subsistence crop levels, and forging linkages with agro-based industries in the region.

Pratap Narain, R. S. Singh, and D. Kumar
Central Arid Zone Research Institute
Jodhpur 342 003
India

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