Effects of Water Stress on Soybean Productivity in Central India

Ajay K. Srivastava, Diwakar Naidu, A. S. R. A. S. Sastri, J. S. Urkurkar, and B. Das Gupta
Indira Gandhi Agricultural University
Raipur, India

In the Chhattisgarh plains in the agroclimatic region of central India (Figure 1), farms may be characterized by one of the following: unbunded lathyritic soils, bunded rice fields (rainfed), bunded rice fields (irrigated), unbunded black soils, or rice bunds. Under these five farming situations, different crop sequences have been in vogue. New crops and crop sequences are recommended by the Agricultural University from time to time based on experimental results.

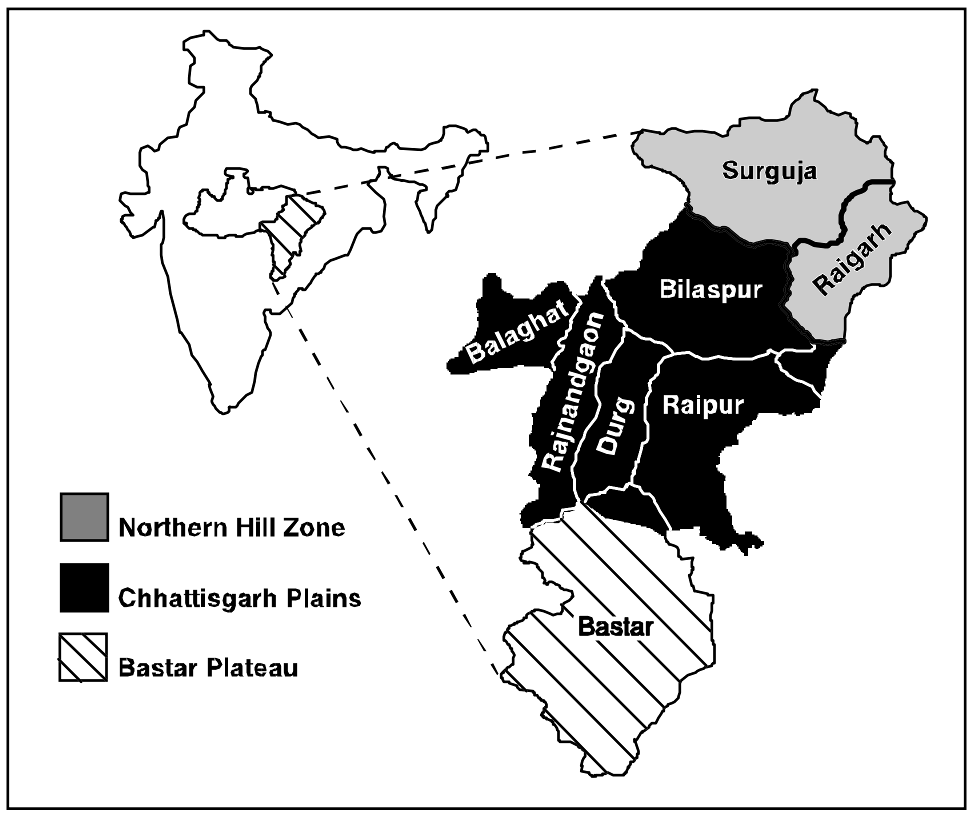

Figure 1. The five farming situations in Chhattisgarh plains, central India.

In the unbunded black soils, farmers usually plant small millets and pigeon pea. However, based on experimental results, the University has recommended soybean followed by chickpea crop sequence under rainfed conditions during monsoon and post-monsoon (winter) seasons, respectively. In the two to three years since that recommendation, the area under soybeans has increased from 3,000 ha to more than 70,000 ha. Experimental results have shown that the evapotranspiration (ET) rate of the soybean crop during peak vegetative and reproductive stages is very high, ranging between 5 mm and 6 mm per day. In view of this, soybeans have been recommended only for heavy soils. Even in black soils with high retention capacity, water stress conditions do occur during dry spells in the monsoon season. After the withdrawal of monsoon rains in September, soybeans sometimes face acute water shortage during the end of reproductive and maturity stages.

The last two years (1994 and 1995) experienced two different rainfall distributions at Raipur, with a seasonal (June–September) rainfall of 1,565.8 mm (1994) and 1,038.0 mm (1995). Rainfall during September 1994 and September 1995 was 206.6 mm and 108.6 mm, respectively. For October 1994 and 1995, the total rainfall was 39.2 mm and 28.4 mm, respectively. Thus, the crop suffered from water stress conditions during 1995 from September on, which is the peak reproductive stage of soybeans in this area. The climatic water balance based on Thornthwaite and Mather's (1955) bookkeeping procedure, using the weekly totals of rainfall and potential evapotranspiration (PET) losses, was computed, and the weekly pattern of water balance parameters in these two years is shown in Figure 2. The soybean crop was sown on 3 July (27th Standard Meteorological Week) in 1994 and 22 June (25th Standard Meteorological Week) in 1995.

A perusal of the weekly water balance diagram of 1995 indicates water deficit conditions during the 26th Standard Meteorological Week (SMW)—one week after sowing—while there was no initial water stress during 1994. In fact, during 1994, heavy rainfall resulted in water surplus conditions right from the sowing week. Also, it can be seen from Figure 2 that water deficit conditions prevailed during the months of September and October in 1995, while in 1994 slight water deficit conditions prevailed during late October.

To examine the effect of water deficit conditions on crop growth, an analysis of water stress at different crop stages has been carried out using the Moisture Availability Index (AE/PE) during the crop-growing season (Figure 3). To examine the intensity of water stress at different crop growth stages, the minimum required Moisture Availability Index (MAI) values have been determined as 75% during seedling stage, 100% during vegetative and reproductive stage, and 50% during maturity stage (slightly modified from the data reported by Patel, et. al. [1986]).

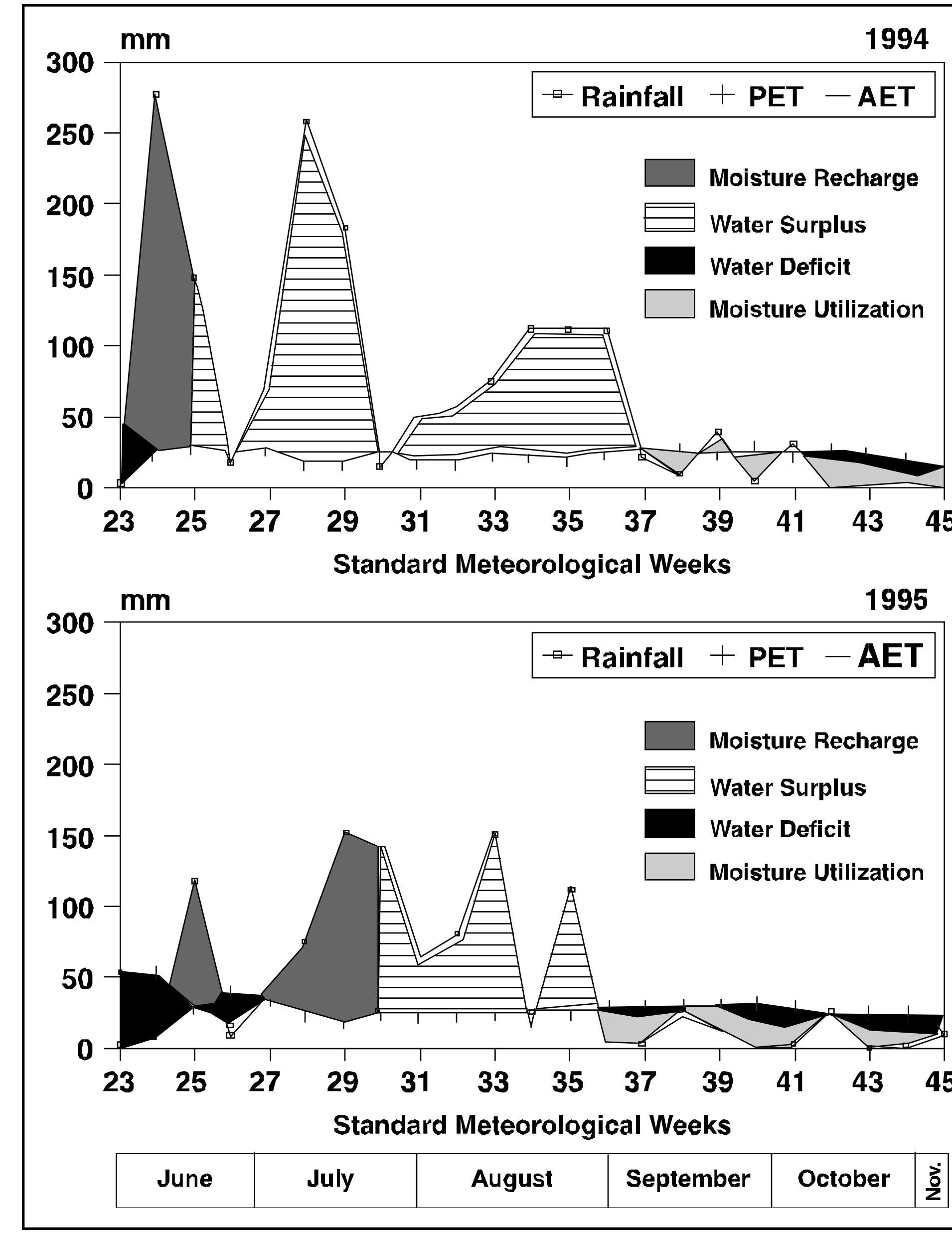

Figure 2. Weekly water balance during the soybean growing season, 1994 and 1995.

It can be seen from Figure 3 that there was water stress during the mid seedling and end of the reproductive stages of the soybean crop in 1995, but there was very little water stress during the end of the reproductive stage in 1994. Thus, the water stress conditions during 1995 were more intensive than in 1994. As a result of this, the productivity of soybeans has decreased from 2.3 t/ha to 1.75 t/ha (a decrease of 0.55 t/ha). However, an examination of total biomass of soybeans indicated that the total biomass during 1994 was 5.51 t/ha, compared to 6.19 t/ha during 1995. This is the result of waterlogging conditions during 1994 in seedling and vegetative stages, which resulted in decreased biomass. However, the grain yield (productivity) was higher

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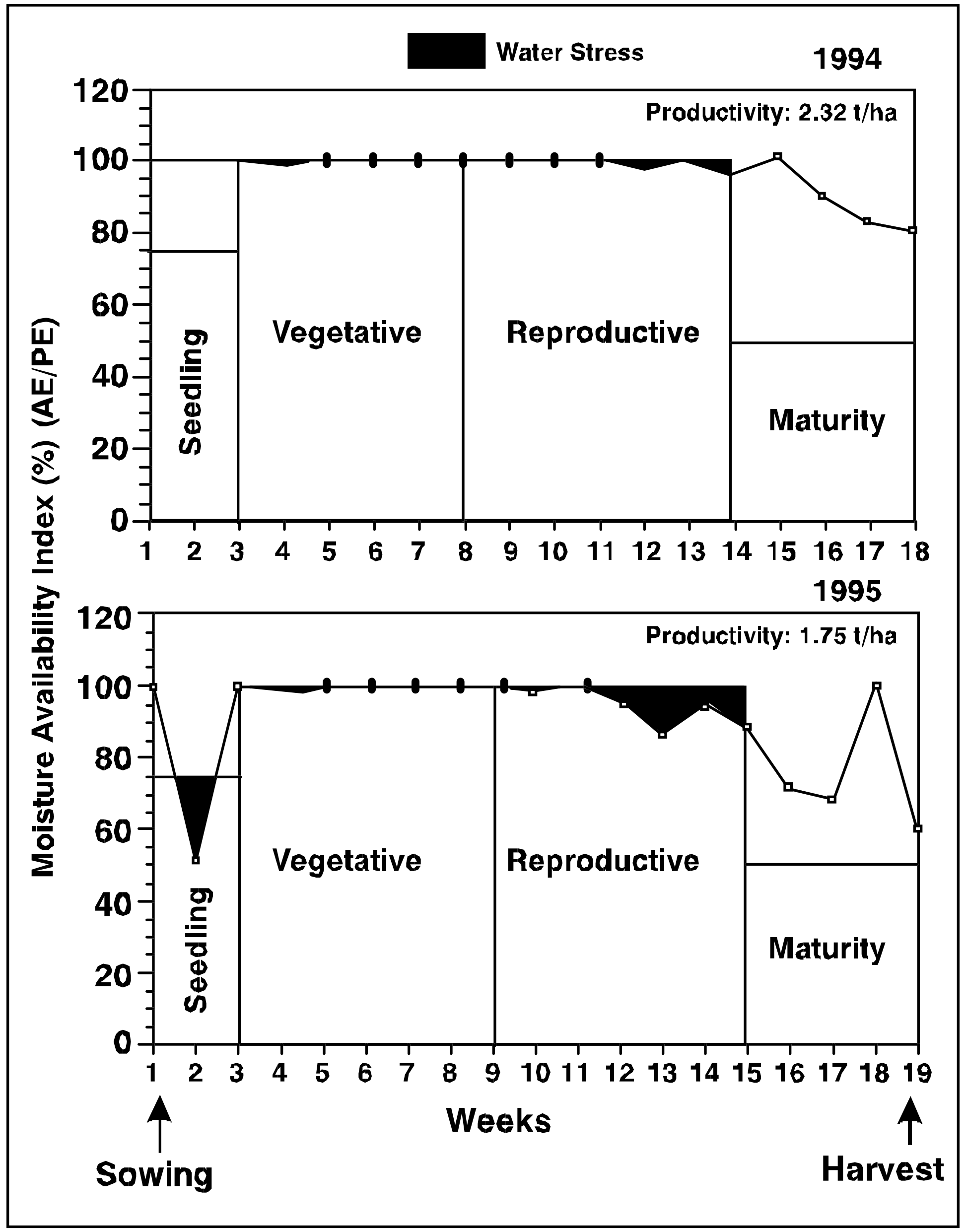

Figure 3. Water stress analysis for soybeans during 1994 and 1995.

because there was no water stress during the reproductive stage of soybeans in 1994. This implies that although the biomass may decrease because of waterlogging conditions during initial stages of crop growth, the productivity increases if evapotranspiration is at potential rate during the reproductive stage for soybeans under Raipur conditions. A small stress (about 15% less than minimum MAI) can reduce productivity by at least 20% in soybeans. In view of this, soybeans are recommended only in heavy soils with good water retention capacity in the Chhattisgarh region of central India.

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