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Impact and Management of Extreme Weather Events in Groundnut Production in India

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Received: 16 Sep 2016 Revised: 10 Oct 2016 Accepted: 28 Nov 2016

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ABSTRACT

The present paper describes the review of research work done on extreme weather events and its impact on groundnut production in India. Amongst the various extreme weather events, only those extreme weather events are considered which have direct relevance to groundnut production. These are low temperature extremes, high temperature extremes and rainfall associated extreme events. Impact of extreme weather events on growth, development and yield of groundnut are described. Since the 80% of groundnut production is from kharif season, more emphasis is given on impact of rainfall distribution, soil moisture, moisture stress and drought on groundnut.

Keywords: Extreme weather, heat wave, chilling, groundnut, moisture stress, drought.

INTRODUCTION

Groundnut (Arachis hypogaea L.) is an important food and oilseed crop grown in diverse agro-climatic environments in India. Among oilseeds crops in India, groundnut accounts for about 50 per cent of planted area and 45 per cent of oil production. In India, about 75 per cent of the groundnut area lies in a low to moderate rainfall zone (parts of the peninsular region and western and central regions) with a short period of duration (90–120 days). Most of the groundnut production is concentrated in five states – Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra which altogether account for about 86 per cent of the total area under groundnut cultivation. The remaining peanut-producing area is scattered among the states of Madhya Pradesh, Uttar Pradesh, Rajasthan, Punjab and Orissa. Although the crop can be grown in all seasons, it is grown mainly in the rainy season (kharif), running
from June to September. The *Kharif* season accounts for about 80 per cent of the total groundnut production. In the southern and south-eastern regions, groundnut is grown in rice fallows during the post-rainy season (*Rabi*), from October to March. If irrigation facilities are available, groundnut can be grown from January to May as a spring or summer crop.

Groundnut is essentially a tropical plant and requires a long and warm growing season. The favorable climate for groundnut is well-distributed rainfall of at least 500 mm during the crop-growing season, accompanied by an abundance of sunshine and relatively warm temperature. Temperature in the range of 25°C to 30°C is optimum for plant development (Weiss, 2000). Once established, groundnut is drought-tolerant, and to some extent it also tolerates flooding. Rainfall of 500 to 1000 mm will allow commercial production, although crop can be produced on as little as 300 to 400 mm of rainfall. Rainfall variations cause major fluctuations in groundnut production in India. Because groundnut is grown mainly as a rainfed crop, there is a high level of fluctuation in production depending on the rainfall.

The impacts of the extreme weather events such as floods, droughts, cyclones, hail storm, thunderstorm, heat and cold waves on the socio-economic state of India is increasing due to large growth of population and its migration towards urban areas which has led to greater vulnerability. De et al. (2005) have reported that in India the extreme weather events have increased considerably over the period of 100 years. Lunagaria, et al. (2015) analysed the trend of extremes of temperature and rainfall in Gujarat and concluded that warm nights are increasing and cold days are decreasing. Annual rainfall and wet days are reported to increase at most of the stations in Gujarat. In view of the increasing population and anticipated climate change and extreme weather events, production must continue to increase to meet the current and future demand for edible oil and vegetable protein in the country. This may be possible through improved agronomic management and genetic improvement of the crop to suit the target environments considering both the current and future climates.

**Extreme weather and groundnut production**

Basically, the climate of India is dominated by the summer monsoon (June to September). From meteorological point of view the entire year is divided into four seasons viz. (i) Winter (December, January and February), (ii) Pre-monsoon or Hot Weather season (March to May), (iii) Southwest or Summer Monsoon season (June to September) and (iv) Post monsoon season (October to November). However, from agriculture point of view there are mainly three crop seasons viz. (i) *Kharif* (rainy season), (ii) *Rabi* (winter season) and (iii) summer season crops. There are several weather aberrations and extreme weather events that occur in different crop growing seasons individually or in combinations with other events, however in the present study we will be confined to mainly those events which occur in groundnut growing regions of India and affect its production. These extreme weather events affecting agricultural production can be grouped into; (i).Low temperature extreme events (ii).High temperature extreme events (iii).Rainfall associated extreme events.

**Impact of low temperature extreme events on groundnut**

The temperature extremes i.e. lowest minimum and highest maximum temperatures recorded at Anand during 1958-2014 period along with monthly normal are depicted in Figure 1. It may be seen there is large difference between the two extremes in every month. During winter season (Dec-March) the differences are more than 35°C while monsoon season these are less. The occurrences of extreme low temperature in association with incursion of dry cold winds from north into the Indian sub continent are known as cold waves. The cold waves mainly affect the areas to the north of 20°N but in association with large amplitude troughs, cold wave conditions are sometimes reported from States like Maharashtra and Karnataka as well. During winter season (December to March) when minimum temperature falls more that 5 °C from its normal, cold wave persists. In India the cold wave conditions during
December and January months did not have any effect on groundnut as during these periods groundnut are generally not grown during winter season. But the extreme cold in February and March, the middle of the planting season of the summer crop, proved to be harmful for the most of the summer crops including groundnut. Germination and growth are adversely affected if the temperature is less than 10 °C (Mohamad, 1984).

Groundnut and other crops that are of subtropical origin are highly susceptible to low temperature damage (Benedict and Ketring 1972; Christiansen 1971; Lyons 1973; Mayland and Cary 1970). There are two types of injury that can occur, chilling and freezing. Low temperature damage in the absence of freezing has been defined as chilling injury (Levitt, 1972). Even though chilling and freezing injury are not the same, structural changes occur in the cell membranes that are similar. Disruption of cellular functions leads to the accumulation of toxic substances and components responsible for off-flavors in fruit and vegetable crops (Singleton and Pattee, 1989). Figure 1 shows that the minimum temperature sometimes fall below 5 °C during December, January and February that may cause frost injury to new seedling of groundnut. Even during March when minimum temperature falls below 10 °C may also result in plant injury. In most of the months the minimum temperature departure from the normal are more than 10 °C. Foggy weather also affect the crop growth and development adversely in most of the groundnut as it reduces the receipt of PAR energy required for photosynthesis by the crop.

**Impact of high temperature extreme events on groundnut**

As winter season transforms into spring the temperature rises initially in the southern parts of India, giving rise to thunderstorms and squally weather which are hazardous in nature. While the southernmost part of the country is free from dust storm and hailstorm, such hazardous weather affect the central, northeastern, north and northwestern parts of the country. Extreme positive departures from the normal maximum temperature result in heat wave during the summer season. These extreme weather events are observed during March to June. However, heat wave like situation arises some times in February also when temperature crosses 35 °C. (Figure 1) shows that at Anand the maximum temperature may exceed by more than 5 °C from its normal in almost every month and sometimes departure may exceed 8 °C resulting in heat wave like situation. Such extreme weather events adversely affect the summer crops.

Hailstorm and thunderstorms causes physical damage to plant resulting in poor growth and yield. The high temperature during flowering stage of the groundnut affects the pollination (Mohamad, 1984). Vara Prasad et al. (2003) reported from the growth chamber study that the seed yield of groundnut decreased progressively by 14%, 59% and 90% as temperature increased from 32/22 to 36/26, 40/30 and 44/34 °C, respectively. Decreased seed yields at high temperature were a result of lower seed-set due to poor pollen viability, and smaller seed size due to decreased seed growth rates and decreased shelling percentages. Seed harvest index decreased from 0.41 to 0.05 as temperature increased from 32/22 to 44/34 °C (Figure 2). Correlations are based on data during the period 1949–50 to 1997–98. The values shown in Figure 3(b) are backward-differenced crop production and monsoon rainfall indices expressed as percentage change from their respective previous year's values (After Krishna Kumar et al. 2004).

**Impact of rainfall associated extreme events**

Rainfall is the most significant climatic factor affecting groundnut production, as 70 per cent of the crop area is found in semi-arid tropical regions characterized by low and erratic rainfall. Low rainfall and prolonged dry spells during the crop growth period are reported to be main reasons for low average yields in most of the regions of Asia and Africa, including India (Reddy et al. 2003), China (Zeyong, 1992) and several parts of Africa (Camberlin and Diop, 1999). In India groundnut yields were reported to be vulnerable from year to year because of large inter-annual variation in rainfall (Sindagi and Reddy, 1972). Bhargava et al. (1974) reported that 89 per cent of yield variation over four regions of India could be attributed to rainfall variability in the August to December growing period. Challinor,
et al. (2003), analysing 25 years of historical groundnut yields in India in relation to seasonal rainfall, concluded that rainfall accounts for over 50 per cent of variance in yield. Gadgil, (2000) observed that the variation in groundnut yield in the Anantapur district arises to a large extent from the variation in the total rainfall during the growing season. Sivakumar and Sharma (1986) compiled a summary water use of groundnut and reported that the water use varies from 250 mm in the rainfed conditions to 830 mm under irrigated conditions. It was observed that seasonal rainfall up to 50 cm is required to sustain a successful groundnut crop in this region. Krishna Kumar et al. (2004) correlated all-India total groundnut production with rainfall over India. They found that July, August and September rainfall index had significant correlations with groundnut production index (Figure 3). However, it may be seen from the (Figure 4). That at local levels the experimental yield at Anand, Gujarat was not in linear relationship with yield of groundnut. Seasonal rainfall at Anand Gujarat exceeding 800 mm had adverse effect on the production resulting in decrease in yield. Also in Anantapur of Andhra Pradesh, the pod yield of groundnut showed a highly significant curvilinear relationship with the use of moisture, namely, adding rainfall and soil moisture (AICRPAM, 2003). A total moisture use of 350–380 mm was found to be optimum for obtaining a maximum yield; a moisture use of either less than this amount or more reduced pod yield. This is because the excess rainfall may have caused more vegetative growth and less reproduction.

Even monthly rainfall at district level had differential effect on pod yield of groundnut in Rajkot and Junagadh districts of Gujarat. At same amount of monthly rainfall there is large difference in the pod yield of groundnut in both the districts (Figure 5 and 6). The vast differences in yield from year to year may be attributed to uneven distribution in the rainfall during a month. The polynomial relationship was found to explain better in comparison to linear relationship particularly in the months of June and July. The higher rainfall during early stages of crop growth may not be useful to groundnut as it may result in more vegetative growth causing disease infestation and less reproductive growth and development. Ong (1986) also showed a poor relationship between groundnut yield and seasonal rainfall, thus highlighting that rainfall distribution is more important to groundnut yield than the amount of rainfall. The yield variability may also be the result of extreme weather events experienced during the crop season. The extreme weather events causing yield losses in groundnut are primarily (i) delay in onset of monsoon rainfall, intermittent dry spells resulting in moisture stress and drought like situation during different stages of groundnut, heavy wet spells and post harvest losses due to unseasonal or prolonged monsoon rainfall.

**Effect of moisture stress and drought**

Rainfall in the semi-arid regions is erratic in duration and distribution, which leads to droughts of varying intensities and durations during the crop season. Hence, the total water use could vary with the stage of crop growth during which moisture stress or droughts occur, and the water-use requirements of the crop at these stages. Results from a series of experiments at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, 1984) showed that early stress or lack of rainfall, soil moisture between 29 and 57 days after sowing did not influence pod yield significantly, whereas pod yields increased by 150 kg/ha, cm of water applied during the seed-filling stage (93–113 days after sowing).

Sivakumar and Sarma (1986) studied the effect of drought stress imposed at different growth phases on the total water use by groundnut and showed that the total water use during the three seasons of experimentation was different for any given growth phase because of the differences in the rainfall during the preceding rainy season (and hence the initial-profile water content) during the three years and because of the differences in the amount of water applied. Williams et al., (1986) have shown that the drought-stress effects on groundnuts depend primarily on the stress pattern. The differential responses of groundnut cultivars to drought were assessed relative to the mean response of all genotypes to three major aspects of drought, (i.e., duration, intensity, and timing relative to crop phenophases) varying independently. The timing of drought was found to have large impact on the variation about the mean response. In general, the sensitivity of a genotype to drought increases with yield potential, increasing the...
closer the drought ends to final harvest. The large variations in the response of genotypes to midseason droughts were due to recovery differences after the drought is relieved. The soil water deficits occurring during flowering and up to the start of the pod growth phase significantly reduced pod yields (in a range of 17–25 per cent) relative to the well-watered control plots for two Spanish and two Virginia cultivars (Wright et al., 1999). The reduction in yield was greatest when severe stress occurred during the pod-filling phase. Several other reports also observed the pod development stage to be most sensitive to moisture deficit (Rao et al., 1985; Stirling, et al., 1989; Fatel and Gangavani 1990).

Analysis of the relationship between simulated groundnut yield and climate showed that yield was predominantly influenced by rainfall from flowering to maturity (Christensen et al., 2004). Naveen et al., (1992) found that water stress imposed during the flowering and pegging stages produced the greatest reductions in pod yield, followed by water stress at early and late pod stages. Nageswara Rao et al., (1985) confirmed that irrigations could be withheld during much of the vegetative period without any apparent effect on pod yield, implying that water stress during the vegetative stage has no effect on yield. Nautiyal et al., (1999) proved that soil moisture deficit for 25 days during the vegetative phase was beneficial for growth and pod yield of groundnut, while Stirling et al., (1989) observed the insensitivity of pod yield to early moisture deficit. Sivakumar and Sharma (1986) imposed drought stress or a soil moisture deficit at all the growth phases of groundnut during three growing seasons and observed that stress from emergence to pegging gave increased yields relative to the control group in the three years of the study, while stress at other stages decreased the yield. Not just yields, but other yield attributes, growth and development are affected by soil moisture deficit or water stress.

The start of flowering and pod elongation are delayed by drought stress (Boote and Ketring, 1990). The rate of flower production is reduced by drought stress during flowering but the total number of flowers per plant is not affected due to an increase in the duration of flowering (Gowda and Hegde, 1986). Boote and Hammond (1981) reported a delay of 11 days in flowering when drought was imposed between 40 and 80 days after sowing. Stansell and Pallas (1979) found that the percentage of mature kernels was reduced to 34 per cent of the control when drought was imposed 36–105 days after sowing. Vorasoot, et al., (2003) observed a drastic reduction in yield and also in yield-attributing characteristics such as total dry weight and shelling percentage when plants were grown at 25 per cent of the field capacity of the soil.

Management options

The management options to mitigate the adverse effect of extreme weather event includes farm management that includes time of sowing, selection of appropriate variety, maintaining plant population, scheduling and methods of irrigation, etc. In addition microclimatic modification such as mulching, shelterbelts etc can be attempted. And the most importantly the forecasting of extreme weather events well in advance.

REFERENCES


Figure 1.Mean monthly maximum temperature (Tmax) and minimum temperature (Tmin) with their extremes recorded at Anand during 1958 to 2014.
Figure 2. Relations between daytime maximum/nighttime minimum temperature and (a) pod yield; (b) seed yield; (c) pod number; and (d) seed number of groundnut at ambient and elevated CO$_2$.

Figure 3. All-India total groundnut production and its association with rainfall over India. (a) Growth in food-grain production. (b) Year-to-year variations in food-grain production and monsoon rainfall. Correlation between groundnut production and (c) monsoon seasonal rainfall and (d) individual monthly rainfall during May to December.
Figure 4. Relationship between pod yield of groundnut and seasonal rainfall at Anand

Figure 5: Monthly rainfall and groundnut production in Rajkot district of Gujarat

y = \(-0.031x^2 + 5.321x + 1037.0\)

\[ R^2 = 0.183 \]

y = \(-0.006x^2 + 3.076x + 774.0\)

\[ R^2 = 0.025 \]

y = 0.590x + 952.0

\[ R^2 = 0.012 \]

y = 1.510x + 881.8

\[ R^2 = 0.040 \]
Figure 6: Monthly rainfall and groundnut production in Junagadh district of Gujarat