3 Effects of Temperature and Rainfall on Sorghum Yield Formation

3.1 Temperature effects on growth and productivity

Temperature has a double role in sorghum. Within an appropriate range it accelerates development and supports rapid canopy formation, but above that range it can shorten critical phases and damage reproductive function. Growth-stage studies show that the most sensitive windows for high-temperature effects on floret fertility lie roughly from 10 to 5 days before anthesis and from 5 days before to 5 days after anthesis. In controlled and field experiments, mean daily temperatures above 25°C during panicle emergence and reproductive development reduced floret fertility sharply, with fertility reaching zero at about 37°C under one experimental setup. When heat occurs later, during grain filling, the main effect shifts from grain number to grain weight because high temperature shortens the effective filling period and limits final kernel mass. Even where sorghum is “heat adapted,” these results make clear that adaptation does not equal immunity. It means the crop can perform better than alternatives under heat, not that it can ignore reproductive heat stress (Prasad et al., 2015; Smith et al., 2023).

3.2 Rainfall effects on crop development and yield

Rainfall affects sorghum yield not simply through total water supply, but through its timing, frequency, and match with soil type and plant stage. In semi-arid regions, rainfall can support germination, early canopy expansion, and reproductive development even when seasonal totals are modest, provided dry spells are short and well-positioned. Conversely, rainfall that arrives too early, too late, or in a few concentrated events can leave the crop exposed to long soil-water deficits during flowering or grain filling. Published case evidence from eastern Ethiopia illustrates this clearly: monthly rainfall amount and rainy-day number during the growing period were positively associated with sorghum yield, while temperature variables were negative. Similar conclusions also appear in dryland studies that emphasize rainfall distribution as more informative than seasonal totals. Rainfall excess can also become damaging. Waterlogging studies show that sorghum yield can decline markedly when excessive moisture occurs, particularly at early stages, because photosynthesis, enzyme activity, and panicle development are impaired. So the rainfall question is not “more or less,” but “when, how often, and under what soil and stage conditions.” (Tolosa et al., 2023; Zhang et al., 2023).

3.3 Heat stress, drought stress, and yield loss mechanisms

Heat stress and drought stress reduce yield through partially distinct but overlapping mechanisms (Figure 2). Heat stress during the pre-anthesis and anthesis period can disrupt tapetum development, pollen viability, pollen germination, and floret fertility, which directly lowers grain number. In one recent study, exposure to 42/32°C day/night heat at the pollen mother cell and booting stages severely disrupted male reproductive development, and 12 days of stress at the PMC stage caused almost complete loss of grain yield. Drought stress, meanwhile, acts through reduced leaf expansion, lower stomatal conductance, reduced assimilate supply, impaired reproductive success, and sometimes premature senescence. Water-deficit experiments further show that drought can alter intra-panicle grain number and depress individual grain weight, depending on timing. Under field conditions, both stresses converge on the same final logic: less successful grain set before flowering and weaker filling after flowering. The stress pathway changes, but the endpoint is the same (Adotey et al., 2021; Prasad et al., 2021; Smith et al., 2023).

3.4 Interactive effects of temperature and rainfall

The most serious yield losses often arise when high temperature and rainfall shortage occur together. Warm conditions increase vapor pressure deficit and evapotranspiration demand; if rainfall is simultaneously low or irregular, the plant faces a compounded water-energy imbalance. That interaction helps explain why a year with only moderate rainfall reduction can still perform poorly if accompanied by strong warming, especially around flowering. Reviews of combined stress in sorghum describe morphological injury, disrupted cell metabolism, lower membrane stability, reduced photosynthesis, and stronger oxidative stress under joint drought-heat exposure than under either stress alone. Modeling studies reinforce the same point. In the U.S. Great Plains, APSIM-based environment characterization identified water- and heat-stress clusters that aligned with observed yield reductions, and in the drier western sorghum belt grain-filling water stress was especially common. This is a reminder that