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Effects of water shortage on food legume crops

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ABSTRACT

The clamor for agricultural resources is being pushed up by global climatic change and population growth. Such consequences are huge challenges to food security, wreaking havoc on the agroecosystem and causing biotic and abiotic stresses in plants, which in turn cause metabolic and physiological problems. Food legume crops contribute to food security in underdeveloped countries by playing an essential role in conservation farming methods. Drought has, nevertheless, exhibited a negative impact on productivity in many parts of the world. While water shortage is a significant abiotic barrier to legume crop output, drought impacts differ depending on drought timing, agro-climatic area, soil texture, and legume species. To resolve these concerns, we gathered data from the recent publications that revealed drought-induced changes in the production of monoculture legumes in field circumstances and examined it using meta-analysis approaches. Research findings revealed that the water cut's quantity was strongly associated with a decrease in yield. However, the magnitude of the effect differed depending on the phenological stage of the drought and legume species. The legumes such as groundnut and lentil exhibited the lowest yield reductions (31.2% and 19.6% for groundnut and lentil, accordingly), however, the biggest yield drop (39.8%) facing the maximum water reduction was for faba bean.

Keywords: Drought, Field studies, Food legumes, Food security, Soybean, Sustainable production.
Article type: Research Article.

INTRODUCTION

Food legumes serve a vital and diverse role in farming systems and poor people's diets worldwide (Vidigal *et al.* 2019; Kebede 2020; Paul *et al.* 2020). They are perfect crops for attaining three developmental goals at the same time in a specific population: poverty reduction, improved human health and nutrition, and increased environmental resilience (Sofi *et al.* 2018; Blackie *et al.* 2019; Iannetta *et al.* 2021; Sekaran *et al.* 2021). Legumes are one of the most significant crops in the world. They may be cultivated in practically any climate and on various

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soils. Legumes, second only to cereals in food security, are an important cash crop for 1 billion smallholder farmers in poor nations, worth roughly US$35 billion yearly (Merga & Haji 2019). Chickpea (4.9%), groundnut (peanut) (4.9%), common bean (8.8%), and soybean (83.8%) exports account for the majority of that economic value (Nigam *et al.* 2021; Pradhan *et al.* 2019). Forages are produced from some legumes, while others are vital contributors to the soil's nitrogen content (Nutt *et al.* 2021). Legumes have been found to decrease the occurrence of several soil illnesses, improve soil erosion resistance, and increase soil nitrogen (N) and carbon (C) content when grown as cover crops or in rotation with cereals (Kumar *et al.* 2018, 2020). Legumes can increase soil permeability and lower bulk density if utilized as fertilizer in conservation agriculture (Rakhimova *et al.* 2021; Shevchenko *et al.* 2021a,b). Thus, encouraging the cultivation of legumes in underdeveloped nations may prove to be a viable strategy for meeting the Millennium Development Goals of economic growth and poverty reduction, increasing health, and ensuring sustainability in the environment (De Notaris *et al.* 2021; Keykha *et al.* 2021). Due to the tendency toward healthy food, legumes' global interest is likely to increase in the years ahead. The interest in legume-based goods is projected to rise as the legumes' medicinal applications become properly recognized and the ailments of eating proteins derived from animals become more generally acknowledged (Kamran & Reddy 2018; Gautam *et al.* 2020; Pathania *et al.* 2020; Tiwari *et al.* 2020). Soluble fibre and protein are abundant in legumes. Consumption of beans regularly has been linked to a lower risk of heart ailments, obesity, stomach disorders, and diabetes (Papandreou *et al.* 2019). As a direct result of this, global legume output has soared over the last 50 years. Compared to what it was in the early 1960s, nowadays global production is higher than thirteen times larger. Production has increased by more than a factor of two even since the year 2000 (Fig. 1; Kebede 2020).

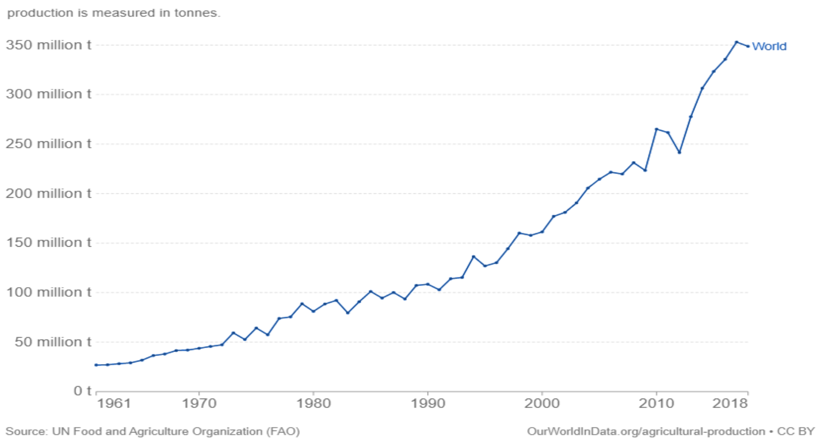

Fig. 1. Global legume production.

In the years ahead, ensuring food security, reducing the danger of climate change, and managing rise in energy demand will become increasingly important concerns (Rani *et al.* 2019). As a result, agriculture and food systems are prioritizing sustainable production. Legume crops can help in this situation by providing numerous functions while adhering to sustainability principles. Soybean dominates legume production, with pulses accounting for roughly 20% of global output over the same period (Foyer *et al.* 2019). Pulses are leguminous crops that are grown on an annual basis that produce one to twelve seeds or grains of varying colour, form, and size within a pod, according to the United Nations' Food and Agricultural Organization (FAO) (Adarsh *et al.* 2019; Peoples *et al.* 2021). Green peas and green beans, which are regarded as vegetable products, along with alfalfa and clover, employed primarily for sowing activities, are not included in this category (Winham *et al.* 2020). Since groundnut and soybean are primarily farmed for oil production, the FAO classification excludes them from the category of pulses (Vollmann 2016). Despite this, the present study will incorporate groundnuts and soybeans into its assessments because they are two of the most important legumes in relation to both production and financial significance. The agricultural sector confronts an imminent dilemma of increasing food productivity by 70% or possibly 100% by 2050, given the estimated 40% rise in the global population (McKenzie & Williams 2015). This problem is exacerbated by urban and industrial development's fierce battle for water and land. Agriculture is pushed to the margins due to this rivalry, where agricultural output is typically limited by water scarcity. The yield of nearly all cultivated plants, including eudicots and monocots legumes and grains, is susceptible to being adversely affected by drought (Sehgal *et al.* 2018). Due to the terminal droughts, the amount of food legumes produced in drylands or semi-arid conditions like the Mediterranean is typically inconsistent or low. This research intends to identify the parameters that influence the amount of reduction in legume production due to stress caused by drought by integrating the results of drought manipulation experiments and field studies conducted all over the world. These variables should be considered in water resources planning to strengthen the resilience of legume producing system. In this investigation, we will refer to drought from an agronomic perspective, which states that drought exists when water scarcity has resulted in a drop in crop yield.

MATERIALS AND METHODS

Fig. 2 shows a flowchart illustration of the process. The database contains every English-language article that was published during that period that satisfied the following requirements: (i) drought-stricken plants were studied under real-world circumstances, and the impact of water shortage was compared to a well-watered state, not in conjunction with other methods, (ii) following to the FAO classification, the crops that were recorded were pulses, groundnuts, or monoculture soybeans, (iii) the yield per unit area response was provided in the papers.

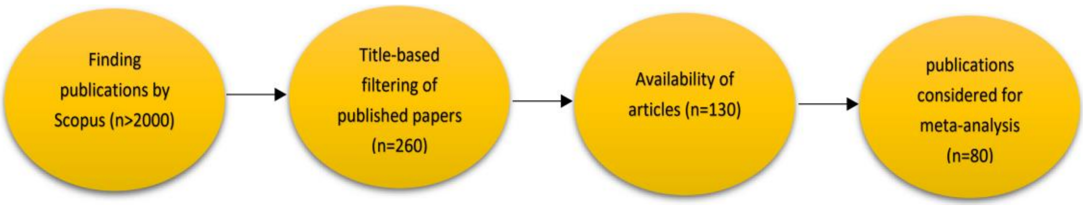

Fig. 2. The procedure of gathering literature data to create a repository for this study is depicted in a flowchart diagram.

Since we are primarily concerned with examining the crop productivity at the species level under the influence of drought, responses of multiple cultivars experiencing the same drought situation were averaged across cultivars. On the other hand, if the same treatment was carried out in several different locations or years, the results were only averaged over all of those locations or years if there was no discernible influence of year or place (Table 1).

Table 1. The geographical variation of all of the research utilized in this study.

Continent	Data points	Total data points (%)
South America	26	4.69
North America	110	19.86
Europe	29	5.23
Australia	65	11.73
Asia	296	53.43
Africa	28	5.05

The extent to which yield responses were affected by the various category variables was of special interest to us. Meta-analysis was conducted on distinct levels for every parameter and classified every find appropriately. Drought intensity indexes that are commonly accepted could not be employed in this analysis because most of the investigations were controlled trials. Rather, for each categorical variable, we estimated observed water reduction. It is the ratio of the amount of water available during times of drought to conditions of adequate rainfall. A one-way analysis of variance (ANOVA) was carried out to compare the water decrease that was observed for each categorical variable. In addition, $p < 0.05$ was utilized as the statistical significance level.

RESULTS AND DISCUSSION

Abiotic stressors are a key stumbling block to crop development and food security worldwide (Akram *et al.* 2018; Chand Jha *et al.* 2021; Banerjee *et al.* 2022). Due to the significant and rapid variations in the global climate, the situation has worsened. Heat and drought are, undoubtedly, the two most significant stresses that have a considerable impact on crop growth and yield. Drought is the abiotic condition that has the greatest impact on legume yield, aside from heat stress and soil deterioration (Smith *et al.* 2019; Kumari *et al.* 2021). The biggest suppliers of pulses, on the other hand, are found in areas where water is scarce. As a result, these countries' agricultural output is significantly reliant on unpredictable rainfall, making them particularly susceptible to drought. As a result, it is necessary to take into account both crop and management aspects because these can dictate how a crop reacts to a lack of water, which can eventually result in a loss of yield. Throughout this study,

we explored the impacts of different crop species, different stages of plant phenology, different climates, different locations, and different soil textures on yield loss. According to the findings of our study, there were substantial variations (p = 0.0185) across legume species in terms of their adaptation to drought, which was evaluated based on each species' capacity to keep producing a high yield after being subjected to a time window of water stress. The lowest yield drop was observed in the legumes' groundnut and lentil (i.e., 31.2% and 19.6% for groundnut and lentil, respectively), whereas the biggest yield reduction was seen in faba bean (39.8%), which was grown under conditions with the largest recorded water reduction (i.e., > 70%). With a minor reduction in water (i.e., 55-70%), the yield reduction in pigeon pea was the least (i.e., 19.7%). Next were common beans (58.9%), green grams (44.1%), cowpeas (43.8%), chickpeas (39.2%), and soybean (27.6%). When compared to chickpea, field pea yields were reduced by just half as much facing the most severe water scarcity (i.e., < 55%). Positive linear relationships were consistently found among observed yield and water reductions throughout a wide variety of legume species, despite the fact that the magnitude of yield reduction differed from species to species (Fig. 3).
Food legumes that have been cultivated originate from all around the world. While certain varieties of legumes have successfully expanded their range beyond the regions in which they were initially cultivated, others have mostly been unable to do so. According to Sprent & Gehlot (2010), most legume plants are indigenous to arid places, whereas groundnut is the sole legume that comes from tropical environments. The wild ancestors of domesticated species have, for the most part, adapted to the conditions of their original habitat during their species' evolutionary history. This has ensured both their survival and that of their offspring.

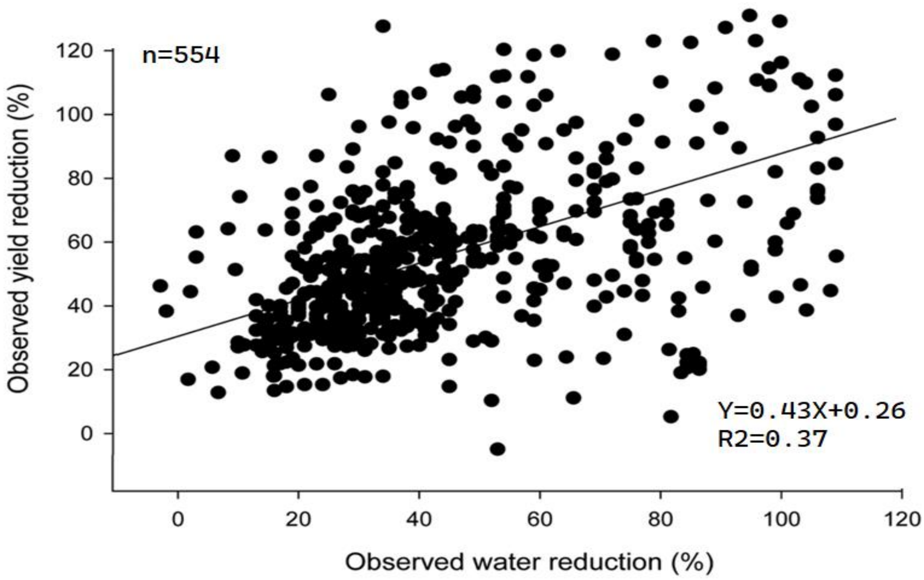

Fig. 3. The correlation between the observed decrease in crop output and the recorded decrease in water use across all legume species.

CONCLUSIONS

Utilizing meta-analytic approaches, the researchers looked at how drought affects legume crop yield and how it varies across different legume species. Significant alterations in the timing and distribution of rain have been seen in several places across the globe, giving rise to increased concerns regarding a growing problem of water scarcity and a growing prevalence of crop failure. This study gives helpful information that may be used to assist agricultural management and to plan reducing production loss caused by drought. This study highlights the importance of prioritizing the drought-resilient legume species development and selecting suitable ones for the world's drought-prone regions. Our findings indicated that drought impacts on the loss of yield differed depending on the species. Since the impacts of drought on legume outputs were revealed to be less influenced by climate zones and much more connected to legume varieties, drought-resistant legume species might be selected and promoted as a way to reduce the effect of droughts.

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