The Journal of Agricultural Science

cambridge.org/ags

Crops and Soils Research Paper

Cite this article: Savala CEN, Wiredu AN, Okoth JO, Kyei-Boahen S (2021). Inoculant, nitrogen and phosphorus improves photosynthesis and water-use efficiency in soybean production. *The Journal of Agricultural Science* 1–14. https://doi.org/10.1017/S0021859621000617

Received: 23 April 2021
Revised: 28 June 2021
Accepted: 6 July 2021

Keywords:
Agroecologies; climate change; determinate; yield

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Inoculant, nitrogen and phosphorus improves photosynthesis and water-use efficiency in soybean production

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Abstract

Soybean yield within the Southern Africa falls below its potential despite similar climatic conditions across some agroecologies, replicable agronomic management practices and introduced improved varieties. Understanding physiological processes and water-use efficiency (WUE) of soybean offer information on bridging this yield gap. A field study was conducted in 2017 and 2018 seasons in two agroecologies (Angonia and Ruace) in Mozambique to evaluate the effects of *Bradyrhizobium diazoefficiens* strain USDA110 formerly known as *Bradyrhizobium japonicum* inoculant, nitrogen and phosphorus on nodulation, physiology and yield of non-promiscuous (Safari) and promiscuous (TGx 1740-2F) soybean varieties. Data on transpiration, photosynthesis, leaf area index, radiation interception and WUE from the beginning of flowering to maturity were collected. Transpiration rate varied considerably with interaction between locations, growth stages, varieties and treatments. At podding, phosphorus-treated soybean at Angonia transpired less (6.3 mmol/m^2/s) than check plants (6.6 mmol/m^2/s). Photosynthesis rate and WUE were distinct with variety, growth stages and inputs within agroecologies. For instance, in Angonia 2018 season, phosphorus fertilized TGx 1740-2F photosynthesized more at flowering (25.3 µmol/m^2/s) while the lowest was phosphorus-treated Safari at podding with 17.2 µmol/m^2/s. At the same site in 2017, inoculated soybean photosynthesized more at 22.8 µmol/m^2/s leading to better WUE of 3.6 that corresponded to 2894 kg/ha yield. Overall, soybean WUE was higher when inoculated than N-treated, while P application yielded better. Results from this study will complement breeders' effort in developing phosphorus efficient varieties suited for a wide range of changing climatical conditions.

Introduction

Introduction of new improved soybean (*Glycine max* L. Merrill) genotypes to smallholder farmers in Southern Africa region aims at increasing productivity. However, yield continue to fall below the varieties production potentials due to climate change regardless of continuous expansion of cultivated land areas, introduction of improved varieties and use of plant nutrients inputs for soybean production (Khojely *et al.*, 2018). Vicissitudes in the regional climatic patterns is threatening future production of soybean. Recently, cropping-seasons have been characterized by frequent events of irregular rainfall and drought both mid- and/or end-season (Ngcamu and Chari, 2020) that warrants better water-use efficiency (WUE) for yield improvement. Technologies for combating irregular rainfall patterns and drought are numerous, chief being water harnessing in reservoirs (during heavy rains) and irrigation. However, smallholder farmers in sub-Saharan Africa (SSA) rarely adopt these due to a plethora of challenges. Instead, they rely heavily on rainfed production of crops. Despite irrigation being key, other agronomic technologies such as: adjusting or changing planting dates, crop varieties, plant density, nutrient and soil moisture management practices can suffice to improve yield.

Judicious management of soil moisture in this changing climate also entails effective and efficient water use by crops. It is projected that soybean production in eastern part of Africa spanning from Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda and Zambia could decline by 12% by 2090 due to water stress if climate change is not mitigated (Tatsumi *et al.*, 2011). The interaction between water supply, temperature and other environmental conditions affects the relationship between WUE and yield which is not necessarily linear and differ with crop species (Condon *et al.*, 2002; Irmak and Specht, 2014). Although some studies have reported WUE impacting yield, it depends on the prevailing abiotic conditions at each growth stage and the affected plant physiological process. For instance, restricting maximum transpiration rate improved WUE leading to 9–13% increase in sorghum yield (Sinclair *et al.*, 2005). Greater yield losses occur when WUE is low due to water stress or higher losses coinciding with the reproductive stage especially between flowering and full seed in soybean. Anda *et al.* (2018) reported a yield loss in two soybean varieties, one water stress-tolerant and the other bred for 'average'