INFLUENCE OF MULCHED-DRIP IRRIGATION SYSTEM ON YIELD AND PHYSIOLOGICAL ATTRIBUTES OF PEPPER VARIETIES IN SOUTHWEST, NIGERIA

[1]I.A. Kehinde, [1*]O.O. Fawibe, [1]A.S. Oyelakin
[1]Department of Pure and Applied Botany, Federal University of Agriculture Abeokuta, PMB 2240, Alabata, Abeokuta, Nigeria
*e-mail: fawibeoo@funaab.edu.ng

ABSTRACT

The unpredictable rainfall pattern due to climate change pose a major challenge to pepper production and its yield outcome in Southwest, Nigeria; therefore, prompting the need for supplementary irrigation practice. The field study assessed the influence of mulched-drip irrigation on yield and agronomic characteristics of three varieties of pepper. The experiment was arranged in a split-plot design with three replicates. The irrigation type; rainfed (RF), drip irrigation with plastic -film (DIP), and drip irrigation with biodegradable film (DIB) served as the main plot while the subplots included three *Capsicum frutescens* varieties: var. baccatum (var. A) var. abbreviatum (var. B), and var. acuminatum (var. C Although the total water supplied to the DIP and DIB increased by 51.7% and 60.3%, respectively compared with RF, the yield of Capsicum also significantly increased by 53.6% and 55.7% under DIP and DIB, respectively. The increased yield outcomes under mulched-drip irrigation were ascribed to the significant increase in chlorophyll content, leaf area and total biomass of Capsicum. Notably, DIP and DIB similarly influenced yield and agronomic attributes of Capsicum; however, DIP saved 13.3% of irrigated water more than DIB. The yield of the *Capsicum frutescens* varieties were comparable. In conclusion, mulched-drip irrigation irrespective of mulch type significantly increased the yield of pepper in Southwest, Nigeria and could serve as supplementary irrigation technique for the promotion of pepper.

Keywords: water-saving irrigation, climate-smart, pepper, intermittent drought

INTRODUCTION

Pepper (*Capscicum frutescens*) is a popular vegetable in West Africa, with economic, food and medicinal importance (Dagnoko *et al.*, 2013). However, its production is heavily dependent on the availability of water, especially during the flowering and fruiting stages (Mackic *et al.*, 2023). Nigeria produces about 50% of the pepper consumed in Africa (Idowu-Agida *et al.*, 2010). Although pepper is widely cultivated throughout Nigeria, yields obtained by farmers are often very low (Idowu-Agida *et al.*, 2010), as a result of the rainfed agricultural practice with unpredictable precipitation patterns. Due to high sensitivity of pepper to shortfall in water supply, plant growth and biomass production are restricted causing severe yield losses (Shama *et al.*, 2019).

Mulched-drip irrigation has become increasingly acceptable and practiced as a water-saving technique that involves the use of drip pipes for water application under a protective film cover (Fawibe *et al.*, 2020; Wang *et al.*, 2023). The technique has been reported as a climate-smart agricultural practice in different regions of the world- China (Wang *et al.*, 2024); Italy (Sifola *et al.*, 2024); India (Job *et al.*, 2018); and Japan (Fawibe *et al.*, 2019). Mulch directly prevents the exchange of water vapour between the soil surface and atmosphere thereby suppress weed growth, reduce soil water evaporation, optimize soil temperature and promote plant growth and yield of high-quality crops (Lamont, 2017; Zhang *et al.*, 2019). In recent years, varying mulch types have been developed with variation in colour and composition (Nithisha et al., 2022). Despite the diverse benefits of plastic films; its removal from the soil after harvest remains difficult and laborious due to the adhesion of the soil particles to the film; hence, resulting in fragmentation of the plastics (Qi *et al.*, 2022). To ensure food security in a sustainable environment, biodegradable mulch (BDM) has been developed. Biodegradable film has shown to disintegrate into CO_2 and H_2O through the process of oxidation and microbial degradation (Amanna *et al.*, 2021). However, it remains unknown if it could produce comparable results with the plastic film mulch. Hence, this study aimed to determine the yield and agronomic characteristics of pepper varieties under mulched drip irrigation techniques compared with conventional cropping practices.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of the Department of Pure and Applied Botany, Federal University of Agriculture, Abeokuta (7.0728ºN, 3,3367ºE) from April to September 2023.

Experimental Design and field management

The experimental plots were arranged in a split-plot design (main plot: irrigation and mulching system; subplot: Capsicum varieties) with three replicates. The main plot consisted of three irrigation and mulching systems: rain-fed (RF), drip irrigation with plastic-film mulching (DIP) and drip irrigation with biodegradable film mulch (DIB). The subplots included three *Capsicum frutescens* varieties: var. baccatum (var A) var. abbreviatum (var. B), and var. acuminatum (var C). The RF plots depended on rainfall and the total amount of rainfall during the experimental period was recorded.

In both DIB and DIP plots, drip tubes, each of 6 m long were laid beneath a black polyethylene plastic film and a biodegradable film, respectively. The drip pipes were connected to a source of water (reservoir) and irrigation water supplied to DIP and DIB was measured with an installed flow meter at 75% field capacity (Fawibe et al., 2020). Basal application of 100 kg/ha of NPK (15:15:15) was carried out, while weeding was done at intervals in all experimental plots when necessary.

Plant Sampling and Analyses

Chlorophyll content and leaf area were measured at vegetative and flowering stages using SPAD-502 (Konica Minolta Co., Ltd.) and leaf area meter (Portable Leaf Area Meter, Hangzhou Mindfull Technology Co. Ltd, China), respectively. Pepper plants covering an area of $1m^2$ were harvested at the maturity stage and oven-dried at 80°C for 72 hours to determine the total biomass. At the fruiting stage, fruit of each variety covering an area of 2 m^2 were harvested weekly for 4 weeks to determine the average yield per hectare. The harvest index and water use efficiency were also calculated.

Statistical analysis

Data were analyzed using Analysis of variance (ANOVA) and means were separated by Duncan’s multiple range test when the effects are significant at $p<0.05$.

RESULTS AND DISCUSSION

The total water supplied to the Capsicum species through DIB and DIP systems were 60.2% and 51.7% higher than that of the RF (Table 1); however, commensurate quantities of yields were produced with an increased rate of 55.7% and 53.6%, respectively (Table 2). The increased yield outcomes could be attributed to the significant increase in photosynthetic-associated parameters such as chlorophyll content and leaf area under both DIB and DIP. The significant increase in chlorophyll concentration and leaf area of Capsicum varieties under DIB and DIP compared to CF enabled both photosystem II and photosystem I to harvest light over a larger surface area thereby producing more assimilates for increased growth and development (Feng *et al*., 2015). The non-significant variation in the growth and yield parameters of the Capsicum varieties under varying treatments could be attributed to the similarity in their ability to adapt to mild water stress caused by intermittent rainfall during the period of plant growth.
Our study shows that the use of either plastic-film or biodegradable film mulch similarly influenced the growth and yield of capsicum varieties; however, DIP saved 19% of irrigated water more than DIB. This is attributable to the texture, thickness, and composition of the materials used. The biodegradable film used in this study was composed of starch-based materials, cellulose acetate, and cellulose nitrate that gradually disintegrated into CO_2 and H_2O through the process of oxidation and microbial degradation (Amanna *et al.*, 2021).

CONCLUSION

The use of drip irrigation with mulching practices (DIB and DIP) significantly increased the yield and agronomic attributes of capsicum varieties compared with the conventional rainfed method by alleviating mild drought stress because of dwindling rainfall pattern especially during the flowering and fruit formation stages.

Table 1. Irrigation precipitation and total water input under rainfed and drip irrigation with different mulch types.

	Irrigation (mm)	Precipitation (mm)	Total water supplied (mm)
RF	35	720	755
DIB	490	720	1210
DIP	425	720	1145

Total water supplied = Irrigation water + precipitation; RF, DIB, and DIP indicate rainfed, drip irrigation with biodegradable mulch, and drip irrigation with plastic film mulch, respectively.

Table 2. Yield, harvest index, and water-use efficiency of Capsicum varieties under varying irrigation and mulching practices.

Irrigation	Varieties	Yield (t/ha)	Fruit length (cm)	Fruit width (cm)	Fruit length-width ratio	Total dry weight (t/ha)	HI	WUE (kg/m^3)
RF	A	2.25^a	2.70^a	1.60^a	1.66^a	3.98^b	0.56^a	0.31^a
	B	2.32^a	2.76^a	1.70^a	1.57^a	4.06^b	0.50^b	0.32^a
	C	2.49^a	2.83^a	1.73^a	1.63^a	4.59^a	0.61^a	0.34^a
DIB	A	3.54^a	3.56^a	2.30^a	1.55^a	6.11^a	0.57^a	0.29^a
	B	3.75^a	3.60^a	2.26^a	1.58^a	6.88^a	0.54^a	0.31^a
	C	3.69^a	3.60^a	2.43^a	1.48^a	6.48^a	0.57^a	0.30^a
DIP	A	3.57^a	3.46^a	2.36^a	1.46^a	6.12^b	0.58^a	0.31^a
	B	3.61^a	3.46^a	2.43^a	1.42^a	6.73^a	0.53^{ab}	0.31^a
	C	3.66^a	3.56^a	2.53^a	1.40^a	6.99^a	0.52^b	0.31^a
Irrigation (I)		***	***	***	***	***	ns	ns
Varieties (V)		ns	ns	ns	ns	*	*	ns
I X V		ns	ns	ns	ns	ns	ns	ns

Values within a column for each irrigation type followed by different superscripts letters are significantly different at p<0.05 by Duncan's multiple range test. * and *** are significant differences at p < 0.05 and p < 0.001 respectively; ns means non-significant by ANOVA. var. baccatum (var. A) var. abbreviatum (var. B), and var. acuminatum (var. C).

Table 3. Chlorophyll content and leaf area of Capsicum varieties under varying irrigation and mulching practices

Irrigation	Varieties	Chlorophyll content		Leaf Area (cm^2)	
		Vegetative stage	Flowering stage	Vegetative stage	Flowering stage
RF	A	26.83^a	25.96^a	10.26^a	27.26^b
	B	27.80^a	26.93^a	11.43^a	30.03^a
	C	27.63^a	27.73^a	12.03^a	30.53^a
DIB	A	38.23^a	38.23^a	19.03^b	60.36^b
	B	39.50^a	38.33^a	19.26^b	69.63^a
	C	37.66^a	38.73^a	21.63^a	74.23^a
DIP	A	38.56^a	39.40^a	13.70^b	53.53^b
	B	39.30^a	38.00^a	15.63^b	58.73^b
	C	38.86^a	40.80^a	18.46^a	68.96^a
Irrigation (I)		***	***	***	***
Varieties (V)		ns	ns	***	***
I X V		ns	ns	ns	ns

Values within a column for each irrigation type followed by different superscripts letters are significantly different at p<0.05 by Duncan's multiple range test. *** indicates significant differences at p < 0.001 while ns means non-significant by ANOVA. var. baccatum (var. A) var. abbreviatum (var. B), and var. acuminatum (var. C).

REFERENCES

Amanna, R., Mahal, Z. Vieira, E.C.S., Samavi, M., Rakshit, S.K. (2021). Plastics: Toward a Circular Bioeconomy. In: Circular Bioeconomy-Current Status and Future Outlook. Biomass, Biofuels, Biochemicals, pg 781-811

Dagnoko, S., Yaro-Diarisso, N., Sanogo, P.N., Adetula, O., Dolo-Nantoume, A.,Gamby-Toure, K., Traore, A., Katile, S. and Diallo-Ba, D. (2013). Overview of pepper (Capsicum spp) in West Africa. African Journal of Agricultural Research, 8(13): 1108-1114

Fawibe, O.O., Honda, K., Taguchi, Y., Park, S. and Isoda, A. (2019). Greenhouse gas emissions from rice field cultivation with drip irrigation and plastic film mulch. Nutrient Cycling in Agroecosystems, 113, 51-62.

Fawibe, O.O., Hiramatsu, M., Taguchi, Y., Junfa, W. and Isoda, A. (2020). Grain yield, water-use efficiency and physiological characteristics of rice cultivars under drip irrigation with plastic-film-mulch. Journal of crop improvement, 34 (3): 414-436.

Feng, Y., Chen, R., Hu, J., Zhao, F., Wang, J., Chu, H. and Lin, X. (2015). Bacillus asahii comes to the fore in organic manure-fertilized alkaline soils. Soil Biology and Biochemistry, 81:186-194.

Idowu-Agida, O.O., Ogunniyan, D.J. and Ajayi, E.O. (2010). Flowering and fruiting behavior of long cayenne pepper (Capsicum frutescens L.) collected from the south eastern Nigeria. Proceedings of the 27th HORTISON, conference, Kano, 11-16th October, 2009, 127-132

Job, M., Rusia, D.K., Dinmani, and Singh, V.K. (2018). Effect of drip irrigation and plastic mulch on yield, water use efficiency of Cauliflower. Journal of Pharmacognosy and Phytochemistry, 2018: 2556-2560

Lamont, W.J. (2017). Plastic mulches for the production of vegetable crops. In: A guide to the manufacture, performance, and potential of plastics in Agriculture. Plastic Design Library pg 45-60

Mackic, K., Bajic, I., Pejic, B., Vlajic, S., Adamovic, B., Popov, O. and Simic, D. (2023). Yield and Water Use Efficiency of Drip irrigation of pepper. Water, 15(16) 2891

Nithisha, A., Bokado, K., Charitha, K.S. (2022). Mulches: Their impact on the crop production. The Pharma Innovation Journal, 11(7): 3597-3603

Qi, Y., Ossowicki, A., Yergeau, E., Vigani, G., Geissen, V. (2022). Plastic mulch film residues in agriculture: impact on soil suppressiveness, plant growth and microbial communities. FEMS Microbiology Ecology, 98 (2)

Shama, S., Leskovar, D., Crosby K. (2019). Genotypic differences in leaf, gas exchange and growth responses to deficit irrigation in reticular and indonus melons (Curcumis melo L). Photosynthetica, 57: 237-247.

Sifola, M.I., Cozzolino, E., Ciancolini, A., Falce, M., Raimo, F., Enotrio, T., Sicignamo, M., Baiano, S. and Paino, L. (2024). Crop management system consisting of biodegradable mulching film + drip irrigation increases yield and quality of flue-cured Tobacco. Sustainability, 16(16): 7089

Wang, J., Fawibe, O.O., Fawibe, K.O. and Isoda, A. (2023). Water productivity, sink production, and varietal differences in panicle structure of rice (Oryza sativa L.) under drip irrigation with plastic-film mulch. Field Crops Research, 291: 1-11.

Wang, C., Li, S., Huang, S. and Feng, X. (2024). A review of the application and impact of drip irrigation under plastic mulch in agricultural ecosystems. Agronomy, 2024 14(8): 1752

Zhang, G., Wu, H., Jiang, K., & Li, Z. (2019). Microplastics in soils: A review of possible sources, analytical methods and ecological impacts. *Journal of Hazardous Materials*, 400, 123328.