



**PERFORMANCE OF CAULIFLOWERS (*Brassica oleracea* var. *botrytis*) VARIETIES AS
AFFECTED BY MOISTURE STRESS AT DIFFERENT STAGES OF GROWTH**

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ABSTRACT

This experiment was conducted at the Research Farm of the Federal College of Forestry, Jos, to determine the response of cauliflower (*Brassica oleracea* var. *botrytis*) varieties to moisture stress at different growth stages. The treatments consist of moisture stress at different growth and development stages (control, juvenile stage, curd formation stage, and head development stage) and two cauliflower varieties (Atria F1 and Summer F1), which were laid out in a split-plot design with 3 replications. The results from this research work reveal that the number of curds per net plot was 11.17, curd length (18.68 cm), curd diameter (39.83 cm), weight of curd per net plot (12.62 kg), and total yield (31.54 t/ha). Varietal difference also significantly influenced growth and yield of cauliflower. Atria F1 had the highest number of curds per net plot (14.50), curd diameter (46.88 cm), curd weight per net plot (16.08 kg), and total yield (40.20 t/ha). Interaction between moisture stress and variety did not significantly influence the growth and yield of cauliflower. It can be concluded that cauliflower performed better when subjected to water stress at the curd formation stage, especially the Atria F1 variety. It can therefore be suggested that cauliflower farmers in Jos and related ecologies should subject cauliflower to water stress at the curd formation stage, especially the Atria F1 variety.

Keywords: Cauliflower, Growth, Moisture stress at Different stages, Yield

INTRODUCTION

A common vegetable in the Brassicaceae family is cauliflower (*Brassica oleracea* var. *botrytis*). Because of its nutritional value and culinary diversity, it is grown and enjoyed all over the world (Singh and Kalia, 2021). Cauliflower has been grown for generations and is said to have originated in the Mediterranean region. White cauliflower is the most popular kind, although it also comes in different colours including green, orange, and purple. It is closely linked to other Brassica crops like cabbage, broccoli, and Brussels (Singh *et al.*, 2025). The wild cabbage, which is believed to have originated in ancient Asia Minor and resembled kale or collards more than the vegetable we know today, is the ancestor of cauliflower. Significant amounts of cauliflower are produced in the United States, France, Italy, India, and China (Singh *et al.*, 2018). The global production of cauliflower was estimated to be between 25 and 50 metric tonnes annually (Singh *et al.*, 2018). With 9.49 metric tonnes produced annually, China is the world's biggest producer of broccoli and cauliflower. With an annual production of 8.84 metric tons, India ranks second. With 1.26 metric tonnes produced annually, the United States of America is the third-largest producer of cauliflower. Asia and the Middle East had average yields of 45 tons per hectare and 39.8 tons per hectare, respectively, according to Sharma *et al.* (2025). Mexico, France, Egypt, Morocco, South Africa, Kenya, and the United Kingdom are among the other nations that have contributed to the world's cauliflower production.

Its characteristic white, curd-like head, which is made up of immature flower buds, is what makes it famous. The crop's curd, which makes up around one-fourth of the entire biomass above ground, is preferred by humans, although cattle can eat the stem and leaves, also referred to as the stalk (Singh *et al.*, 2018). The nutritional profile of this vegetable makes it very valuable. It has few calories and is a good source of vitamins C and K, dietary fiber, and a number of minerals, such as manganese, potassium, and magnesium. Antioxidants and potentially health-promoting substances, including sulforaphane and glucosinolates, which have been shown to have anticancer effects, are also present in cauliflower (Picchi *et al.*, 2020).

Compared to other locations like Europe or North America, cauliflower has not historically been a frequently grown crop in African nations. To satisfy local and regional needs, cauliflower is grown in a few African nations. One of Africa's top producers of cauliflower is Egypt. Many states in Nigeria grow cauliflower, including Jos, Plateau State, Kaduna State, Kano, Nasarawa, and Benue states (Bashiru, 2015).

Africa's cauliflower industry has a number of obstacles, including poor availability of high-quality seeds, poor post-harvest handling and storage infrastructure, pests and diseases, and a lack of market connections. Nonetheless, research, technology distribution, and capacity building programs are being used to enhance cauliflower production (Victor *et al.*, 2020). Crop water requirements are one of the goals of irrigation techniques that give

crops the water they need to meet their unique water requirements, FAO (2018). Crop type, development stage, soil conditions, and climate are some of the variables that affect these requirements.

According to Droppers *et al.* (2021), plants that are grown with inadequate water levels exhibit poor growth and, in extreme situations, progressive death of the plant's stem. They are also more prone to disease and less able to withstand insect feeding. When plants don't have enough water to meet their needs, it's referred to as moisture stress or drought stress. Low rainfall, high temperatures, or poor soil structure that hinders water absorption and retention by the roots are some of the causes of this (Bijl *et al.*, 2018). Moisture-stressed plants may exhibit symptoms like wilting, decreased growth, and the emergence of lighter, smaller fruits and vegetables. Reduced yields and potential crop failure have been linked to water stress in crops. However, different plant species are affected differently by water stress. The plant wilts when it experiences water stress because the water pressure inside the leaves drops. Reduced photosynthesis, the process by which plants mix water, carbon dioxide, and light to produce carbohydrates for energy, is the primary effect of moisture stress on growth and development. Plant growth may be adversely affected by chemical constraints brought on by decreases in essential photosynthetic elements like water. Maintaining plant growth requires the ability to identify early signs of water stress, the most prevalent of which is wilting (Bhattacharya, 2021).

Additionally, they claim that cultivating drought-tolerant crops is one approach to avoid the problems caused by insufficient water supply.

Vegetable production is significantly influenced by crop variety. Therefore, selecting the right kinds for maximum productivity is crucial. Several cauliflower cultivars can be planted at different times of the year. It is impossible to overstate the significance of choosing the right cauliflower varieties to plant during the dry season. Even in ideal circumstances, poor varietal selection can lead to decreased production and unmarketable curds (Begna, 2020). Yield and quality can be maximized by choosing the right cauliflower types according to local climate circumstances, growth needs, and consumer preferences (Angadi *et al.*, 2025). Rich in nutrients, cauliflower has numerous health advantages, such as lowering the risk of heart disease and cancer (Chaudhari *et al.*, 2024). However, many regions are suffering increasingly frequent and severe droughts as a result of climate change, which may have a detrimental effect on cauliflower output. During these crucial times of water constraint, farmers must deal with challenging circumstances. How long can crops resist dry conditions when growing vegetables? Therefore, it is necessary to find drought-tolerant cauliflower types and to create management strategies that might lessen the impact of moisture stress on cauliflower output. This study aims to close this gap by assessing how moisture stress affects the performance of cauliflower types.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Research Farm of the Federal College of Forestry, Jos, in Plateau State. It is a location in Nigeria's middle belt, 1,200 meters above sea level, and lies between latitudes 9.9° N and 8.8° E. The region's vegetation is a typical Guinea savannah, and it receives 1200 mm of rainfall on average each year. Rainfall typically begins in April and ends in September or October, with a temperature range from 20 to 30° C (FCF Jos, 2020).

Soil Sampling and Analysis

Soil samples of the experimental fields were randomly collected at 0 - 15cm depths from different locations before land preparation. The soil samples were analyzed for physical and chemical properties using standard procedures as described by Black (1965).

Treatments and Experimental Design

The experimental treatments consist of two cauliflower varieties (Atria 153 F1 and Summer White F1) and four moisture stress stages (juvenile stage, curd formation stage, head development stage, and a control. The treatments were laid out in a split-plot design with 3 replications. Moisture stress stage was assigned to the main plots, while varieties were assigned to the sub-plots. The blocks were separated by 2.0 m, while the basins in each block were separated by 0.5 m, which served as a buffer to minimize lateral movement of water from one basin to another. The crop was sown in November, 2024 using a 3m x 3m (Sunken bed) well-leveled basin plot size.

At the initial stage, all treatments were kept at field capacity. While at the control stage, full water application was given to the crop at field capacity throughout the period of the experiment. At the juvenile stage (4WAT), moisture stress was imposed on the crop until it started to show visible signs of wilting, then water was supplied. Similarly, at the curd formation stage (7 WAT), moisture stress was imposed until visible signs of water stress began to show, then water continued to be supplied. Furthermore, moisture stress imposition took effect at the curd development (9 WAT) stage until visible signs of wilting manifest then water was given to the crop.

Surface irrigation was carried out by allowing the water to fill the sunken beds at field capacity before imposing the treatments. Water was withdrawn at different growth stages from the plots as prescribed by the treatments at Control, Juvenile stage, curd formation stage and head development stage. The control treatment was, however, irrigated at field capacity all through the period of the experiment.

Cultural Practices

Land Preparation

The land was prepared by ploughing and harrowing to a fine tilth to facilitate deeper rooting and moisture penetration. Plots were marked out and made into sunken beds with waterways between pairs of beds set at a distance of 2m apart to prevent the flow of water into other beds. The land was irrigated before transplanting to facilitate soil leveling and a second irrigation just after sowing. Equal depths of irrigation water of 40mm

were applied before the proposed treatment levels of water stress were imposed. This allows proper establishment of the crop.

Nursery Preparation and Transplanting

Seeds of Cauliflower were purchased from certified dealers and sown on a seedling tray with a mixture of cocopeat for germination until it is ready for transplanting. Light irrigation was done as often as necessary to keep the nursery adequately moist.

Seedlings were transplanted at 5 weeks after sowing on sunken beds at a spacing of 60cm x 50 cm inter- and intra-row spacing when the seedlings produced 2-3 true leaves. Seedlings were irrigated as soon as possible after transplanting. The seedlings were placed vertically into the ground and not sideways. This is to avoid a condition known as “J rooting”. This condition results in a J-shaped root system that ultimately decreases yield and head size (Sharma et al., 2025).

Each plot was fertilized with 150 g NPK (16:16:16) twice at 2 WAT and 6 WAT (Jagdish, 2022).

Data Collection and Analysis

Data were collected on the following by tagging five plants randomly from each net plot.

Number of curds per hectare: The number of curds at harvest was counted in each plot and recorded; it will be later extrapolated to the number of curds per hectare.

Number of curds/Ha

$$= \frac{\text{No. of Curds for the whole Plots} \times 10,000 \text{ m}^2}{\text{whole plot size m}^2}$$

Curds Length (cm): The lengths of five curds from the tagged plants were measured

using a meter rule and the mean taken at harvest.

Curds Diameter: The diameters of the curds tagged were measured by the use of Vernier caliper.

Weight of Curd/net plot (kg): The curds in the net plot will be weighed after counting.

Total Yield (kg/ha): The average weight of the cauliflower was measured in grams using a weighing scale. The average weight for each treatment was divided by 1000 to get the kilogram value. Thereafter, yield was calculated as the kilogram value divided by the plot size and expressed in 10,000m² to give the yield in kilograms per hectare.

Total Yield (kg/ha)

$$= \frac{\text{Weight of Curd per net plot (kg)} \times 10,000 \text{ m}^2}{\text{Net Plot Size m}^2}$$

Data collected on the above parameters were subjected to analysis of variance using Genstat 17th edition. Significant treatment means were ranked using Student Newman Keuls (SNK).

RESULTS

Physio-chemical Properties of the soil

Table 1 displays the soil analysis results for the growth season. According to the analytical findings, the soil at the Federal College of Forestry trial site was textured sandy loam. The soil's pH (H₂O) of 6.11, which was within the range of 6.0 to 7.0 appropriate for cucumber development, indicated that it had a greater capacity to hold water (Delgado and Gómez, 2024). The before and post soil analysis results of Amoakwah et al. (2020) were consistent with

the organic carbon (OC) concentration of 0.958 Kg^{-1} . According to Delgado & Gómez (2024), who evaluated the soil's cation exchange capacity (CEC) as $12.8 \text{ cmol kg}^{-1}$ based on soil analysis, the soil's CEC value was $3.370 \text{ cmol kg}^{-1}$, which might be regarded as low. According to Delgado & Gómez (2024), who assessed total N at 0.05 g kg^{-1} as low, the soil's total nitrogen was 0.140 g kg^{-1} , which may be regarded as high.

Number of Curd Per Net Plot

In Table 2, results demonstrated that the amount of curd generated per net plot is highly influenced by moisture stress. The control treatment produced more curds (15.67 curds), followed by juvenile and curd formation (14.50 curds), which are comparable, while the curd development stage produced the fewest curds per plot (11.17 curds). There was no interaction between moisture stress and variety in terms of the quantity of curds per plot, and Atria F1 generated more curds per net plot (14.50) than Summer F1, which produced roughly 13 curds.

Curd Length (cm)

At various phases of cauliflower growth, curd length was found to react strongly to moisture stress (Table 2). The control treatment had the longest curd (23.90 cm), which was followed by the juvenile stage (21.83 cm), the curd formation stage (20.83 cm), and the curd growth stage (18.68 cm). Regarding curd length, there was no discernible variation between the kinds or the relationship between moisture stress and variety.

Curd Diameter (cm)

The results in Table 2 showed that moisture stress significantly influences the curd diameter. Higher curd diameters were obtained at the control treatment (50.38 cm) followed by Juvenile (47.0 cm) and curd formation (46.76), which are identical with each other, while the least number of curds per plot was counted during the curd development stage (39.83 cm).

Significant varietal difference was recorded for Atria F1 (46.88 cm), while Summer F1 (45.11 cm) produced larger and smaller diameters respectively. No interaction between moisture stress and variety in terms of curd diameter was measured.

Weight of Curd Per Net Plot (kg)

The result in Table 2 showed that moisture stress significantly influences the weight curd per net plot. Higher curd weights were obtained at the control treatment (18.22 kg) followed by Juvenile (16.17 kg) and curd formation (15.99 kg) which are equivalent with each other while the least weight of curds per plot was counted during the curd development stage (12.62 kg).

Significant varietal difference was recorded for Atria F1 (16.08 kg) while Summer F1 (15.42 kg) produces larger and smaller diameters respectively. No interaction between moisture stress and variety in terms of curd weight was measured.

Total Yield (t/ha)

The result in Table 2 showed that moisture stress significantly influences the total yield. Higher yields were obtained at the control treatment (45.54 t/ha) followed by Juvenile (40.42 t/ha) and curd formation (39.97 t/ha)

which are equal footing with each other while the least yield per plot was counted during the curd development stage (12.62 kg).

Significant varietal difference was recorded for Atria F1 (40.20 t/ha) while Summer F1 (38.54 t/ha) produces higher and lower yields, respectively. No interaction between moisture stress and variety in terms of total yield was measured.

DISCUSSION

The results presented in Table 2 reveal a clear and statistically significant influence of moisture stress imposed at different growth stages on the yield and yield components of cauliflower. Plants grown under the control condition (no moisture stress) consistently recorded the highest values for number of curds per net plot, curd length, curd diameter, curd weight, and total yield. This outcome reflects the fundamental role of adequate soil moisture in sustaining key physiological processes such as photosynthesis, nutrient uptake, cell division, and cell expansion (Ethan and Umar, 2001). Under optimal moisture conditions, plants maintain high stomatal conductance, which facilitates carbon dioxide assimilation and enhances carbohydrate production. These assimilates are efficiently translocated to developing sinks, resulting in improved curd growth and overall yield.

Moisture stress imposed at the juvenile stage and curd formation stage resulted in moderate reductions in yield parameters. At the juvenile stage, water stress likely limited leaf area development through reduced cell expansion and decreased turgor pressure.

This would have constrained light interception and photosynthetic capacity, ultimately reducing biomass accumulation. However, the relatively moderate reduction observed suggests that cauliflower plants retain some capacity for recovery if favorable moisture conditions are restored. Similarly, stress during the curd formation stage may have interfered with the initiation and early development of the curd by reducing assimilate availability and enzymatic activity associated with growth processes. Nonetheless, the effects were not as severe as those observed at later stages, indicating partial resilience during early reproductive development.

The most pronounced reduction in all measured parameters occurred when moisture stress was imposed at the curd development stage. This stage represents a critical period characterized by rapid cell division and enlargement within the curd, requiring a continuous supply of assimilates and adequate turgor pressure. Water stress at this stage likely induced stomatal closure, thereby reducing photosynthetic rates and limiting carbohydrate synthesis. In addition, impaired phloem transport under water deficit conditions would have restricted the movement of assimilates to the developing curd. Increased respiration under stress may have further depleted available carbohydrates, resulting in reduced curd size, weight, and overall yield. These findings align with established crop physiological principles that reproductive and yield-forming stages are highly sensitive to

environmental stress, particularly water deficit (Ahmed *et al.*, 2023).

Varietal differences were also evident, with Atria F1 outperforming Summer F1 in most yield parameters, including number of curds, curd diameter, curd weight, and total yield. This suggests inherent genetic variation in traits such as water use efficiency, root system development, and the ability to maintain physiological activity under suboptimal moisture conditions. The non-significant difference observed in curd length indicates that this trait may be less influenced by genetic factors or less sensitive to moisture variability compared to other yield components (Parkash *et al.*, 2021).

The interaction between moisture stress stages and variety was not significant for all measured parameters, indicating that both varieties responded similarly to the imposed moisture stress conditions. This suggests that the effect of moisture availability was more pronounced than varietal differences, and that moisture stress at critical growth stages exerts a dominant influence on cauliflower yield irrespective of genotype.

Additionally, Abd El-Mageed *et al.* (2018) discovered that whereas only average fruit weight was considerably lower in 80% than 100%, both the number of fruits per plant and average fruit weight were significantly lower in 60% water application compared to 100%.

In a different study,

When exposed to moisture stress, cultivar differences were found to have a substantial impact on cauliflower growth and yield. This is due to variations in species or morphological traits. Because of this, the

Atria F1 variety yields significantly more than the summer F1 variety. According to Abd El-Mageed *et al.* (2018), determinate cultivars yield between 15 and 30 t/ha, whereas indeterminate cultivars can generate up to 91 to 150 t/ha for greenhouse production. Abd El-Mageed *et al.* (2018) that a lack of water throughout the maize crop's blooming cycle (tasselling and silking) results in a drop in yield components and grain yield. The variation observed may have been the reason for the differences between the varieties in all the growth and yield characters examined in this study. There were no significant moisture stress and varietal interactions for the plant growth and yield parameters.

The results demonstrate that adequate moisture supply is essential for optimal cauliflower production, and that water stress during the curd development stage has the most detrimental effect on yield. This is primarily due to its direct interference with assimilate production, translocation, and utilization during a period of high sink demand. These findings underscore the importance of proper irrigation management, particularly during reproductive growth stages, to maximize yield and ensure crop productivity.

CONCLUSION

Based on the outcome of the findings achieved in the study area, it can be concluded that the yield parameters of cauliflower varieties were significantly affected by moisture stress and the Atria F1 variety performed better than the Summer F1

variety grown under moisture stress. Therefore, it can be concluded that cauliflower performed better when subjected to water stress at the curd formation stage, especially the Atria F1 variety. It can

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therefore, be suggested that cauliflower farmers in Jos and related ecologies should subject cauliflower to water stress at the curd formation stage, especially the Atria F1 variety.

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Table 1: Physio-chemical Properties of the soils of the Experimental Sites during 2024 Dry Season in Jos, Plateau State.

Properties of Soil	Inference
Physical properties	
Particle size distribution (g kg ⁻¹)	
Sand	75.00
Silt	18.00
Clay	7.00
Texture	Sandy Loam
Chemical properties	
pH H ₂ O	6.11
pH (CaCl ₂)	6.00
Organic carbon (g kg ⁻¹)	0.958
Total nitrogen (g kg ⁻¹)	0.140
Available Phosphorus (mg/kg)	22.417
Electrical conductivity(ds/m)	0.051
Exchangeable Cations (Cmol kg ⁻¹)	
Ca ⁺⁺	1.719
Mg ⁺⁺	0.548
K ⁺	0.223
Na ⁺⁺	0.379
CEC	3.370
Exchangeable bases	0.501

Source: Soil Laboratory, FCF, Jo

Table 2: Response of Cauliflower Varieties to Moisture Stages on Yield Characters

Treatment	Number of Curds Per Net Plot	Curd Length (cm)	Curd Diameter (cm)	Weight of Curd Per Net Plot (kg)	Total Yield (t/ha)
Moisture Stage					
Control	15.67 ^a	23.90 ^a	50.38 ^a	18.22 ^a	45.54 ^a
Juvenile Stage	14.50 ^b	21.83 ^{ab}	47.00 ^b	16.17 ^b	40.42 ^b
Curd Formation Stage	14.50 ^b	20.83 ^b	46.76 ^b	15.99 ^b	39.97 ^b
Curd Development Stage	11.17 ^c	18.68 ^c	39.83 ^c	12.62 ^c	31.54 ^c
SE±	0.486	0.795	1.279	0.756	1.889
Sig	**	**	**	**	**
Variety					
Atria F1	14.50 ^a	21.35	46.88 ^a	16.08 ^a	40.20 ^a
Summer F1	13.42 ^b	21.09	45.11 ^b	15.42 ^b	38.54 ^b
SE±	0.243	0.398	0.640	0.378	0.945
Sig.	**	NS	*	*	*
Interaction (MSS * V)					
Sig.	NS	NS	NS	NS	NS

Means within a column having different letters are significant at the 5% level of probability using Student Newman Keuls (SNK), WAT = Weeks after Transplanting, SE = Standard Error, NS = Not Significant, ** = Significant at $p \leq 0.01$