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EFFECTS OF WATER APPLICATION ON THE YIELD OF SELECTED CROPS IN KATSINA STATE

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ABSTRACT

*This study examined the effects of water application on the yield of tomato (*Solanum lycopersicum*), okra (*Abelmoschus esculentus*), and sesame (*Sesamum indicum*) across three agro-ecological zones in Katsina State, Nigeria. Field experiments were conducted using a randomized block design with eighteen 2×2 m plots per zone, divided into mulched and un-mulched treatments under three staggered planting periods (early, normal, and late). A uniform irrigation regime of 25 liters applied four times weekly was maintained, and crops were harvested after 90 days. Regression analysis was used to assess the relationship between water application and crop yield. Tomato recorded a strong positive correlation between water application and yield across all zones, particularly during the late planting period ($r = 0.986–0.999$), with a coefficient of determination $r^2 = 0.998$. Okra yielded higher in un-mulched plots across all three zones, achieving a perfect correlation coefficient of $r = 1.000$ during the early planting period. For sesame, while water application positively influenced yield in all zones, the central zone under mulched conditions recorded the weakest relationship ($r = 0.191$; $r^2 = 0.036$), indicating that mulched water application contributed only approximately 3.6% to sesame yield in that zone. Un-mulched plots in the same zone, however, returned a perfect positive correlation of $r = 1.000$. The study concluded that water quantity alone does not determine crop yield, as identical water applications under different cultivation practices produced yield differentials. Further research is recommended to clarify the role of climatic factors in influencing crop yield in the area.*

Keywords: Water, Application, Mulching, Planting period, Crop yield, Katsina State

1. INTRODUCTION

Water scarcity and semi-arid conditions significantly limit crop productivity in northern Nigeria. Irrigation is critical to supplement rainfall and maintain high yields in vegetable and seed crops. Tomato *(Solanum lycopersicum),* okra *(Abelmoschus esculentus), and* sesame *(Sesamum indicum)* are widely cultivated and economically important in Katsina State. Previous studies indicate that irrigation frequency, soil moisture management, and planting time significantly affect crop growth and yield (Hernandez, 2016; Hailu, Kidane, & Teklu, 2018; Sedara, Mohammed, & Bello, 2021). Mulching conserves soil moisture and moderates temperature, but its impact varies with crop type. Few studies in Nigeria have evaluated irrigation, mulching, and staggered planting together across multiple agro-ecological zones.

The agricultural potential of Katsina State has been largely acknowledged, but several factors limit the realization of this potential. Insufficient water availability due to high rainfall variability and inadequacy as well as frequent droughts together with poor soil fertility is considered the main ecological constraints. Studies by Baiyeri, Yusuf, Obalowu, Saad, & Banjoko (2020); Brendel (2020); and Shareef, Ma, Chen, & Niu (2021) have revealed that insufficient water availability and frequent droughts and farmers limited technology know-how, managerial and financial capacities as well as structural, economic and institutional weakness in the sub-Sahara has greatly affect the crops production potentials of these countries.

The staple crops widely cultivated in the region are millet, sorghum, maize, groundnut, cowpea, cotton, sesame, okra, tomato. Tomato, okra, and sesame are among the economically significant crops cultivated in Katsina State. Farmers who depend heavily on staple crops such as tomato, okra, and sesame are particularly vulnerable, as these crops are highly sensitive to the timing, amount, and distribution of water. Yet, in Katsina State, water has become not only scarce but also increasingly difficult to manage effectively. The yields of tomato and okra sharply decline under insufficient water supply, especially during flowering and fruit-setting stages where moisture stress leads to severe blossom drop, poor fruit development, and reduced marketable yield. Sesame, although naturally drought tolerant, suffers drastic yield losses when water deficits occur during early vegetative and flowering phases, resulting in poor branching, fewer capsules, and low-quality seed. Conversely, excessive or poorly timed irrigation, common in some fadama and irrigated areas, contributes to waterlogging, disease outbreaks, nutrient depletion, and reduced productivity. Despite these known physiological responses, farmers in Katsina continue to apply water based on guesswork, tradition, and inconsistent access to irrigation facilities rather than on scientifically established crop-water requirements.

Studies on impact of water application on crop yield have been carried out in parts of Nigeria. These include; Akinbile, & Sangodoyin (2010) on rice in Ibadan Oyo State, Shareef, Ma, Chen & Niu (2021) on okra in Maiduguri and Yakubu, Sani, Igbadun, Ganiyu & Sani (2022) on tomato in Bauchi State. In Katsina State, there are studies that relate climate and crop such as those of El-tantawi & Saleh (2013); Adeniyi & Yahaya (2019) focused on rain fed farming for maize yield. The importance of vegetables in the human diet cannot be over emphasized and the demand for vegetables is all year round though its supply is somehow seasonal. Farmers in Katsina State engaged in rain-fed cultivation of vegetables such as okra, spinach, tomato, water-leave, because of its quick return on investment an economic empowerment. It is on this premise that this study attempts to investigate the effect of water application and planting schedules on the yield of selected crops in Katsina State. This study fills this knowledge gap and provides practical recommendations for sustainable water management in semi-arid agriculture.

2. MATERIAL AND METHODS

Katsina State is located in northwestern Nigeria. Katsina State lies between latitudes 11°08′00” N and 13°22′00” N and longitudes 6°52′00” E and 9°20′00” E (figure 1). The state shares an international boundary with Niger to the north and is bordered by Jigawa State and Kano State to the east, Kaduna State to the south, and Zamfara State to the west. The climate of the state is characterized by a semi-arid tropical climate, with a distinct wet season (May–September) and dry season (October–April). Annual rainfall ranges between 500 mm and 800 mm, decreasing from the southern to the northern parts of the state. Mean daily temperatures range from 21°C to 38°C (El-Tantawi, & Saleh, 2013). For the purpose of this study, Katsina State was divided into three agro-ecological zones: Northern zone, Central zone and Southern zone. These zones differ slightly in rainfall distribution, soil properties, and temperature conditions, which influence agricultural productivity and irrigation requirements (El-Tantawi, & Saleh, 2013).

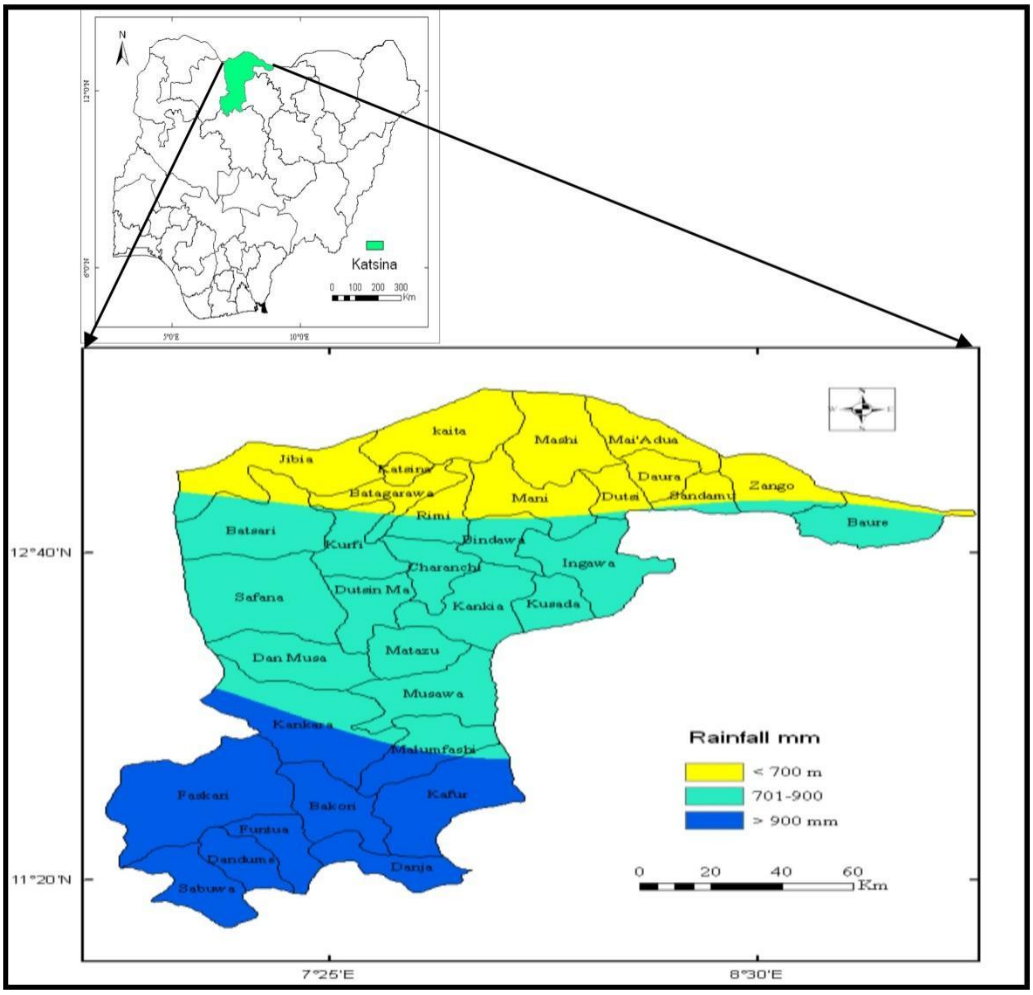

Figure 1(a) Showing Nigeria with Katsina state insert. (b) showing agro-ecological zones of Katsina

2.1 Methods of Data Collection

The experiment employed a randomized block design consisting of 18 plots per ecological zone. Each plot measured 2 m × 2 m and was arranged in three rows and three columns to accommodate three staggered planting periods. Plots were divided into Mulched plots, covered with dry grass and un-mulched plots are left bare. Each treatment was replicated across the three ecological zones. Planting was staggered into three periods; Early planting,15 October Normal planting,15 November and Late planting 15 December. Each planting stage was separated by an interval of one month. All plots received the same irrigation treatment; 25 liters of water applied four times per week; irrigation was stopped two weeks before harvest. All crops were harvested 90 days after planting. Data obtained finally was on quantity of water applied and yield obtained and measured in grammes per plot for both mulched and un-mulched.

2.2 Method of Data Analysis

Regression analysis was used to determine the relationship between irrigation water application and crop yield across the ecological zones and planting periods. Correlation coefficients (r) and coefficients of determination (r^2) were used to determine the strength of relationships between water application and crop yield across the different ecological zones.

3 RESULTS AND DISCUSSION

3.1 Effects of Water Application on the Yield of Selected Crops in Katsina State

The experimental farms were located at Musa Yar adu university Katsina for the northern zone, Songhai farms in Dutsinma for the central zone and Katsina Agricultural and Rural Development Authority in Funtua for the southern zone. Randomized blocks of 9 plots measuring 2 by 2 meters each and arranged in 3 rows and 3 columns to accommodate the 3 staggered planting periods for the 3 selected crops was replicate for both mulch and un-mulch practices. This makes a total of 18 plots in each ecological zone. Early planting was done on the 15th of October and thereafter an interval of one month was used to space the early, normal and late planting periods. The same agronomic practices were maintained for all plots and same water quantity of 25 litres was applied four times a week. Water was withdrawn two weeks to harvest and all crops were harvested after 90 days. The regression results for water application effect on the yield of selected crops are presented on Tables 1,2 and 3.

3.2 Effects of Water Application on the Yield of Tomato in Katsina

Six plots of size 2x2 meters were established in the three ecological zones in the state, these are northern, central and southern zones. The six plots were treated equally in terms of water applications but three were covered with dry grass to serve as mulch while the remaining three were left bare as un-mulch. Planting was staggered in both mulch and un-mulch plots into early, normal and late planting periods with one month interval between each stage of planting. Early planting commenced on 15th October on both mulch and un-mulch plots, exactly one month after normal planting was done and late was also done one month after normal planting. The result of the effect of water application on the yield of tomato in the various planting schedules (dates) in the three zones is presented on Table 1. The results on Table 1 showed a strong positive relationship between water application and the yield of tomato in the three ecological zones. In the northern zone result shows that yield increases slightly with each date of planting with the highest yield obtained during the late planting (Early $r = 0.986$, Normal $r = 0.988$ and Late $r = 0.999$). The same pattern of result was observed for the central and southern ecological zones. However, a closer observation of the regression. results for water application and the yield of tomato in Kastina State showed a strong positive relationship in all the three ecological zones. The southern zone exhibited a perfect positive correlation with value of $r = 1.00$ and $r^2 = 1.00$, while the northern and central zones show positive values of $r = 0.999$ ($r^2 = 0.998$) and $r = 0.999$ ($r^2 = 0.9978$). The result also shows that the yields from the mulched plots were higher than those in the un-mulched plots.

The result for the effect of water application on the yield of tomato in the three ecological zones in Katsina state shows that water plays a very vital role in the final yield of tomato in the locations. Early planting in the study area commenced in October, by then rainfall cessation has started in the north and central zones therefore final yield is completely dependent on irrigation water applied. In the southern zone, the same quantity of water applied through irrigation is augmented by occasional rainfall, hence the perfect relationship between water and tomato yield in the southern zone. Hernandez, (2016) revealed that both under and over application of water to the tomato crop has a negative impact. Under application of water can reduce photosynthesis, transpiration, stomata conductance, leading to lower carbon assimilation and water use efficiency (Chaves, 2017). It also impairs nutrient uptake and transport, especially calcium, which can cause physiological disorders such as blossom-end rot, growth cracks, and sun scald in the fruit (Farooq, 2018). Too much water can be detrimental to tomato plants, as it can cause a number of problems, such as: root rot, blossom end rot, fruit cracking, and also resulted in sun scald.

Table 1: Summary of Regression Analysis for Water Application and Tomato Yield in Katsina

TOMATOES

ZONES	OKRO PLANTING PERIOD		MULCH								UNMULCH							
			R (correlation)	RSquare	Fstattitics	F Sig.	B Coefficient	t-test	Sig.	95% Confidence linterval for B	R (correlation)	RSquare	Fstattitics	F Sig.	Beta Coefficient	t-test	Sig.	95% Confidence linterval for B
CENTRAL	EARLY	Water Application	0.975	0.952	592.808	0.000	-0.322	-24.348	0.000	(-0.349 - -0.295)	0.993	0.987	2482.764	0.000	-0.249	-49.827	0.000	(-259-0.239)
		Water Amt/wk(l)	0.975	0.952	592.808	0.000	0.026	24.348	0.000	0.024-0.028	0.993	0.987	2482.764	0.000	0.020	49.827	0.000	0.019-0.021
	NORMAL	Water Application	0.990	0.979	1440.522	0.000	-0.402	-37.954	0.000	(-0.424--0.380)	0.979	0.959	791.017	0.000	-0.704	-28.125	0.000	(-0.754--0.653)
		Water Amt/wk(l)	0.990	0.979	1440.522	0.000	0.031	37.954	0.000	0.030-0.034	0.979	0.959	791.017	0.000	0.006	28.125	0.000	0.052-0.060
	LATE	Water Application	0.999	0.997	10741.443	0.000	-0.274	-103.641	0.000	(-0.280 - -0.269)	0.999	0.997	12119.491	0.000	-0.275	-110.075	0.000	(-0.280 - -0.270)
		Water Amt/wk(l)	0.999	0.997	10741.443	0.000	0.022	103.641	0.000	0.022-0.022	0.999	0.997	12119.491	0.000	0.022	110.075	0.000	0.022-0.022
NORTHERN	EARLY	Water Application	0.988	0.975	1906.036	0.000	-1.535	-43.658	0.000	(-1.605--1.464)	0.996	0.992	6663.868	0.000	-1.92	-81.633	0.000	(-1.968--1.873)
		Water Amt/wk(l)	0.988	0.975	1906.036	0.000	0.123	43.658	0.000	0.117-0.128	0.996	0.992	6663.868	0.000	0.154	81.633	0.000	0.150-0.150
	NORMAL	Water Application	0.986	0,973	1713.142	0.000	-1.305	-41.390	0.000	(-1.368--1.242)	1.000	1.000	1219193.821	0.000	-1.336	-1135.867	0.000	(-1.368--1.334)
		Water Amt/wk(l)	1.986	0,974	1714.142	0.000	0.104	41.390	0.000	0.099-0.109	1.000	1.000	1219193.821	0.000	0.107	1135.867	0.000	0.107-0.107
	LATE	Water Application	0.999	0.999	44947.218	0.000	-0.903	-212.008	0.000	(-0.912--0.895)	0.991	0.982	2866.458	0.000	-1.207	-53.539	0.000	(-1.252--1.162)
		Water Amt/wk(l)	0.999	0.999	44947.218	0.000	0.072	212.008	0.000	0.072-0.073	0.991	0.982	2866.458	0.000	0.097	53.539	0.000	0.093-0.100
SOUTHERN	EARLY	Water Application	1.000	1.000	849335.740	0.000	-0.238	-921.594	0.000	(-0.238 - -0.237)	0.991	0.981	1710.369	0.000	-0.465	-41.357	0.000	(-0.488 - -0.443)
		Water Amt/wk(l)	1.000	1.000	849335.740	0.000	0.019	921.594	0.000	0.019-0.019	0.991	0.981	1710.369	0.000	0.037	41.357	0.000	0.035-0.039
	NORMAL	Water Application	0.999	0.999	21128.039	0.000	-0.749	-145.355	0.000	(-0.760 - -0.797)	0.996	0.991	3802.772	0.000	-1.080	-61.667	0.000	(-1.115 - -1.044)
		Water Amt/wk(l)	0.999	0.999	21128.039	0.000	0.060	145.355	0.000	0.059-0.061	0.996	0.991	3802.772	0.000	0.086	61.667	0.000	0.084-0.089
	LATE	Water Application	0.996	0.993	4163.528	0.000	-0.998	-64.525	0.000	(-1.029 - -0.966)	0.996	0.991	3802.772	0.000	-1.018	-61.667	0.000	(-1.115 - -1.044)
		Water Amt/wk(l)	0.996	0.993	4163.528	0.000	0.080	64.525	0.000	0.077-0.082	0.996	0.991	3802.772	0.000	0.086	61.667	0.000	0.084-0.089

3.3 *Effects of Water Application on the Yield of Okra in Katsina*

The results of water application on the yield of Okra in the three agro-ecological zones of Katina State are presented on Table 2. Major findings on Table 2 shows that yield in the un-mulch plots in the ecological zones are higher than the yield in the mulch plots in all the ecological zones. This result is similar to findings by Al – Harbi, Al-Orman, & Adgham, (2008) who explained that control irrigation is essential for high yields in Okra cultivation, because the crop is sensitive to both surface and around (seeping) irrigation. This goes to show that mulching in the three ecological zones limits the rate of water evaporation, it retains high moisture in the soil which Al – Harbi, Al-Orman, & Adgham, (2008) also noted is detrimental to Okra yield.

The staggered planting periods do not have much significant effect on the yield of Okra in all locations. It was further observed that the yield of Okra in the northern zone responded more positively to water application than the central and southern region. Higher temperature in the north ensures that the Okra plant absorbs sufficient water for physiological development and excess is evaporated. Sedara, Mohammed, & Bello, (2021) explained that Okra requires adequate water supply and relative moist soil throughout the growing season in order to have high yield. They also posited that the flowering and the fruiting stage of okra is considered to be the most sensitive in the entire growing season. And that water shortage at this stage reduces the yield of okra.

Results also revealed that yield response to water application in all the ecological zones under mulch and un – mulch plots show a slight decreased in yield with the staggered periods of early, normal and late planting except in the northern zone where early planting shows an insignificant response to water application practice. is very sensitive to temperature variation, water logging and extreme drought. The poor yield performance in the early planting season in the northern zone can be attributed to low temperature and drought condition. Davis (2022) also observed that the saline content of water applied to okra also reduces the transpiration and causes an imbalance in evapo-transpiration rate and induces the reduction in yield.

Among the abiotic stresses such as heat, cold, drought and salinity, the salt stress exerts more drastic effect in terms of low productivity. The most important process that is affected by salinity is photosynthesis. Reduced photosynthesis under salinity is not only attributed to stomatal closure leading to reduction of inter cellular CO_2 assimilation, but also to non-stomatal factors like reduction in green pigment and leaf area. There is also increasing evidence that salts affect photosynthetic enzymes, chlorophylls and ionic content (Davis, 2022).

Also, the insignificant effect of water application on yield of okra observed in the late planting period in the southern zone can be explained by the fact that by mid-December the abiotic stress factors earlier discussed are in high play in the southern zone. Therefore, according to Singh (2018) if the quantity of water applied is not up to 60% above evapo – transpiration, yield will be affected. He noted that maximum yield will be achieved above 60% and decreased yield will be the case if it is below 60%. He also estimates total water consumption of okra throughout its growth stage as 43.8 cm (438mm).

Table 2: Summary of Regression Analysis for Water Application and Okra Yield in Katsina

			OKORO															
			MULCH								UNMULCH							
ZONES	OKRO PLANTING PERIOD		R(correlation coefficient)	R Square	F stattitics	F Sig.	B Coefficient	t-test	Sig.	95% Confidence linterval for B	R (correlation coefficient)	R Square	F stattitics	F Sig.	Beta Coefficient	t-test	Sig.	95% Confidence linterval for B
CENTRAL	EARLY	Water Application	0.996	0.993	941.525	0.000	-1.753	-30.684	0.000	-1.869 - -1.638	1.000	1.000	3444707.156	0.000	-1.347	-1855.992	0.000	(-1.348 - -1.345)
		Water Amt/wk(l)	0.979	0.958	941.525	0.000	0.140	30.684	0.000	0.131 - 0.150	0.996	0.991	3444707.155	0.000	0.108	1855.992	0.000	0.108 - 1.080
	NORMAL	Water Application	0.597	0.356	22.901	0.000	-0.329	-4.786	0.000	-0.468 - -0.190)	1.000	1.000	12706454.859	0.000	-0.862	-3564.612	0.000	(-0.863- -0.862
		Water Amt/wk(l)	0.597	0.356	22.901	0.000	0.026	-3564.612	0.000	0.015 - 0.037	1.000	1.000	12706454.858	0.000	0.069	3564.610	0.000	0.069 - 0.069
	LATE	Water Application	0.778	0.605	63.230	0.000	-1.024	-7.952	0.000	-1.284 - -0.764	1.000	1.000	17351495.549	0.000	-1.008	-4165.513	0.000	(-1.008 - -1.007)
		Water Amt/wk(l)	0.778	0.605	63.230	0.000	0.082	7.952	0.000	0.061 - 0.103	1.000	1.000	17351495.549	0.000	0.081	4165.513	0.000	0.081 - 0.081
NORTHERN	EARLY	Water Application	0.160	0.026	0.727	0.401	-0.190	-0.853	0.401	-0.647 - 0.267	1.000	1.000	5135622.946	0.000	10.682	2266.191	0.000	(-0.683 - -0.683)
		Water Amt/wk(l)	0.160	0.026	0.727	0.401	0.015	0.853	0.401	(-0.021 - 0.052)	1.000	1.000	5135622.946	0.000	0.055	2266.191	0.000	0.055 - 0.055
	NORMAL	Water Application	0.942	0.887	217.339	0.000	-0.830	-14.742	0.000	(-0.946 - -0.715)	1.000	1.000	5915821.566	0.000	-0.732	-2432.246	0.000	(-0.733 - -0.732)
		Water Amt/wk(l)	0.942	0.887	217.339	0.000	0.066	14.742	0.000	0.057 - 0.076	1.000	1.000	5915821.566	0.000	0.059	2432.246	0.000	0.059 - 0.059
	LATE	Water Application	0.993	0.986	2022.307	0.000	-0.798	-44.970	0.000	(-0.835 - -0.762)	1.000	1.000	13161234.380	0.000	-1.092	-3627.842	0.000	(-1.093 - -1.092)
		Water Amt/wk(l)	0.993	0.986	2022.307	0.000	0.064	44.970	0.000	0.061 - 0.067	1.000	1.000	13161234.380	0.000	0.087	3627.842	0.000	0.087 - 0.087
SOUTHERN	EARLY	Water Application	0.986	0.972	809.756	0.000	-1.340	-28.456	0.000	(-1.437 - -1.242)	1.000	1.000			-1.060	-300944161.775	0.000	(-1.060 - -1.060)
		Water Amt/wk(l)	0.986	0.972	809.756	0.000	0.107	28.456	0.000	0.099 - 0.115	1.000	1.000			0.085			0.085 - 0.085
	NORMAL	Water Application	0.982	0.954	628.049	0.000	-1.084	-25.061	0.000	(-1.174 - -0.995)	1.000	1.000	2922548.719	0.000	-0.558	-1709.546	0.000	(-0.558 - -0.557)
		Water Amt/wk(l)	0.982	0.964	628.049	0.000	0.087	25.061	0.000	0.080 - 0.094	1.000	1.000	2922548.719	0.000	0.045	1709.546	0.000	0.045 - 0.045
	LATE	Water Application	0.608	0.369	13.637	0.001	-0.379	-3.693	0.001	(-0.592 - -0.167)	0.038	0.001	0.030	0.865	0.033	0.172	0.865	(-0.363 - -0.429)
		Water Amt/wk(l)	0.986	0.972	809.765	0.000	-0.379	-3.693	0.001	(-0.592 - -0.167)	1.000	1.000	0.085		0.033	0.172	0.865	(-0.363 - -0.429)

3.4 Effects of Water Application on the Yield of Sesame in Katsina

The result of the analysis of water application on the yield of sesame in Katsina state is presented on Table 3. Findings on Table 3 showed that though relationship between water application and yield of sesame were positive in all agro ecological zones, the central ecological zone recorded the lowest under the mulch condition with r value of 0.191 during the early planting period. With an r^2 value of 0.036 it simply means that water application under mulch condition in the central zone contributes only about 3.6% to the yield of sesame which is highly insignificant. However, results under the un-mulch condition in the same location returned a very strong and positive relationship with correlation coefficient (r) of 1.000. This means that in as much as water application improves the yield of sesame, too much application or the conservation of moisture to ensure wet conditions around the plant is detrimental to the final yield of the crop. This finding agreed with the works of Hailu, Kidane, & Teklu (2018) who observed that Sesame is a very important crop with drought resistant characteristics and suitable for cultivation in semiarid areas than other crops.

The northern ecological zone which has drier conditions than the other parts of the state however exhibited stronger relationship between water application and the yield of Sesame under both mulch and un-mulch conditions especially during late planting period. The late planting is done in December when rainfall has long ceased in that location. So, water application under such harsh weather conditions will evaporate quickly because of high temperature. This means that in Sesame, like other crops, grain filling period is of great importance in determining production. Although Sarhadi & Sharif (2014) opined that the grain filling period is influenced by plant genetics, environmental stresses such as drought can cause yield loss.

Relationship between water application and the yield of Sesame in the southern ecological zone was relatively strong for both mulched and un-mulched plots. This is because the southern zone enjoys more element weather than the other parts of the state. The late planting which commenced in December depends entirely on water application also like the other zones. However, the period heralds the advent of the harmattan period which though it is dry and harsh, yet with very cold conditions that inhibits the rate of evaporations especially at night and lowers temperature. Many authors for example (Tantawy, Abdel-Mawgoud, El-Nemr & Chamoun, 2007; Sarhadi & Sharif, 2014; Golestani & Pakniya, 2015; and Hailu, & Teklu, 2022) agreed that Sesame yield is significantly affected by the amount of irrigation water applied and its application method. It was observed that Sesame yield decreases northwards from the southern zone, this attest to the fact that the yield of Sesame was affected by water deficiency and these decreases yield considerably especially if the water shortage occurs during the flowering or grain filling stages.

Table 3: Summary of Regression Analysis for Water Application and Sesame Yield in Katsina

			SESAMA															
ZONES	PLANTIN G PERIOD		MULCH								UNMULCH							
			R (correlation)	R Square	F stattitics	F Sig.	B Coefficient	t-test	Sig.	95% Confidence linterval for B	R (correlation)	R Square	F stattitics	F Sig.	Beta Coefficient	t-test	Sig.	95% Confidence linterval for B
CENTRAL	EARLY	Water Application	0.191	0.036	1.307	0.261	-0.323	-1.143	0.261	(-0.897 - 0.251)	1.000	1.000			-0.655			(-0.655 - -0.665)
		Water Amt/wk(l)	0.191	0.036	1.307	0.261	0.026	1.143	0.261	(-0.020 - -0.072)	1.000	1.000			0.052			0.052 - 0.052
	NORMAL	Water Application	0.253	0.064	2.353	0.134	-0.324	-1.534	0.134	(-0.754 - 0.105)	0.475	0.225	8.346	0.007	-0.345	-2.889	0.007	(-0.604 - -0.103-
		Water Amt/wk(l)	0.253	0.064	2.353	0.134	0.026	1.534	0.134	(-008 - 0.060)	0.475	0.225	8.346	0.007	0.028	2.889	0.007	0.008 - 0.048
	LATE	Water Application	0.388	0.150	6.110	0.019	-0.486	-2.472	0.019	(-0886 - -0.087)	0.447	0.199	7.144	0.012	0.039	2.472	0.019	(-0.661 - -0.088)
		Water Amt/wk(l)	0.388	0.150	6.110	0.019	0.039	2.472	0.019	0.007 - 0.071	0.447	0.199	7.144	0.012	0.030	2.672	0.012	0.007 - 0.053
NORTHERN	EARLY	Water Application	0.402	0.161	11.427	0.001	-0.609	-3.380	0.001	(-0.979 - -0.249)	0.398	0.159	7.982	0.007	-0.722	-2.825	0.007	(-1.238 - -0.206)
		Water Amt/wk(l)	0.402	0.161	11.427	0.001	0.049	3.380	0.001	0.020 -0.078	0.398	0.159	11.427	0.007	0.058	2.825	0.007	0.017 - 0.099
	NORMAL	Water Application	0.488	0.238	18.584	0.000	-0.811	-4.311	0.000	(-1.188 - -0.435)	0.399	0.159	8.024	0.007	-0.338	-2.833	0.007	(-0.579 - -0.097)
		Water Amt/wk(l)	0.488	0.238	18.584	0.000	0.065	4.311	0.000	0.035 - 0.095	0.399	0.159	8.024	0.007	0.027	2.833	0.007	0.008 - 0.046
	LATE	Water Application	1.000	0.999	106716.588	0.000	-1.049	-326.675	0.000	(-1.055 - -1.042)	1.000	1.000	106716.588	0.000	0.084	326.675	0.000	(-1.525 - -1.525)
		Water Amt/wk(l)	1.000	0.999	106716.588	0.000	0.084	326.675	0.000	0.083 - 0.084	1.000	1.000			0.122	436620398.317	0.000	0.122 - 0.122
SOUTTHERN	EARLY	Water Application	0.702	0.493	32.630	0.000	-1.029	-5.712	0.000	(-1.481 - -0.704)	0.448	0.200	7.576	0.010	-0.329	-2.752	0.010	(-0.572 - -0.085)
		Water Amt/wk(l)	0.702	0.493	32.630	0.000	0.087	5.172	0.000	0.056 - 0.119	0.448	0.200	7.576	0.010	0.026	2.752	0.010	0.007 - 0.046
	NORMAL	Water Application	0.976	0.953	675.068	0.000	-1.702	-25.982	0.000	(-1.835 - -1.568)	1.000	1.000	675.068	0.000	0.136	25.982	0.000	(1.550 - --1.550)
		Water Amt/wk(l)	0.976	0.953	675.068	0.000	0.136	25.982	0.000	0.125 - 0.147	1.000	1.000			0.124			0.124 - 0.124
	LATE	Water Application	0.975	0.950	634.541	0.000	-2.318	-25.190	0.000	(-2.506 - -2.131)	1.000	1.000			-1.020	-260819616.539	0.000	(-1.020 - -1.020)
		Water Amt/wk(l)	0.975	0.950	634.541	0.000	0.185	25.190	0.000	0.171 - 0.200	1.000	1.000			0.082			0.082 - 0.082

3. Conclusion

This study examined the effects of water application on the yield of selected crops across three agro-ecological zones of Katsina State, Nigeria. Field experiments conducted in the northern, central, and southern zones revealed that irrigation water application significantly influences crop productivity in semi-arid environments, although the magnitude of this influence varies among crops and environmental conditions. The results showed a very strong positive relationship between irrigation water application and tomato yield across all ecological zones. Tomato yields were consistently higher in mulched plots than in un-mulched plots, indicating that soil moisture conservation through mulching enhances tomato productivity. This finding highlights the importance of maintaining adequate soil moisture levels for optimal tomato growth, especially during the dry season when rainfall is limited.

In contrast, okra yields were generally higher in un-mulched plots, suggesting that excessive soil moisture retention under mulch may negatively affect the crop. Okra appears to perform better under moderate soil moisture conditions where evaporation allows excess water to dissipate. The findings also indicate that the northern ecological zone exhibited a stronger yield response to irrigation due to higher temperatures and evapotranspiration rates. Sesame demonstrated a positive but variable response to irrigation water application across the ecological zones. While irrigation improved sesame yield, excessive moisture retention under mulched conditions reduced productivity in some cases. This observation reflects the drought-tolerant nature of sesame, which performs better under moderate moisture conditions rather than excessive soil wetness. Overall, the study confirms that irrigation water management plays a critical role in determining crop productivity in semi-arid agricultural systems. However, the effectiveness of irrigation practices depends largely on crop type, soil moisture management techniques, and environmental conditions.

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