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Research article

Response of irrigated tomato (*Solanum lycopersicum* Mill) to mulch application rates

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ABSTRACT

Rapid decline in available water for crop production has led to the adoption of irrigation schedules for meeting water supply throughout cropping seasons. Nonetheless, the loss of water from soil often results in spells of water stress between schedules, which adversely affect crop yield. Hence, the use of mulch in conserving soil moisture in irrigated farming is becoming popular among farmers. In this study, a two-year screenhouse pot experiment was conducted to evaluate the effects of *Pennisetum purpureum* (Pp) mulch on tomato (*Roma* variety) grown in daily irrigation (IF_{daily}), irrigation at 3-days interval (IF_3), and irrigation at 5-days interval (IF_5) conditions. The Pp mulch was chopped to 5 cm and applied on the soil surface of each experimental pot at 1 t ha^{-1} (Pp_1), 2 t ha^{-1} (Pp_2), 3 t ha^{-1} (Pp_3), and 4 t ha^{-1} (Pp_4). These rates were compared against a bare soil as control (Pp_0). The treatments were laid in a completely randomised design with four replicates. Tomato yield decreased by 53.6% and 26.6% in IF_3, and 86.2% and 65.0% in IF_5 compared with IF_{daily} in years 1 and 2, respectively. Among mulch rates, Pp_4 and Pp_3 increased tomato yield respectively by 107.5% and 99.9% compared with Pp_0, while Pp_2 and Pp_1 were similar in year 1. In year 2, mulch increased tomato yield by 84.1% (Pp_1) – 215.3% (Pp_4) and contributed substantially to tomato yield in IF_{daily} ($R^2 = 0.99$; $p < 0.01$); IF_3 ($R^2 = 0.93$; $p < 0.01$); and IF_5 ($R^2 = 0.25$; $p < 0.05$). However, withdrawing irrigation at 5 days interval was detrimental to tomato yield production.

1. Introduction

Food and agricultural production are key indices of a nation's growth and development. Although great achievements in food and agriculture have been attained around the world (Alexandratos, 1999), the continuing growth in human population necessitates an increase in competition for water among various users (farmers, industrialists, households, etc.) to meet the rising demand for food and other products (Godfray et al., 2010; Oshunsanya et al., 2016; Aliku and Oshunsanya, 2016, 2017). Consequently, increase in water demand over limited resources has led to a continuous decline in available water for agricultural production (Aliku, 2017). Hence, there is an urgent need for water management in agricultural production. Aliku and Oshunsanya (2016) adduced that significant improvements in irrigation water management can be achieved through irrigation scheduling. This could depend on the required irrigation frequency per crop type, crop variety and environmental conditions. Although the adoption of irrigation frequency in water management has been reported beneficial to water balance, fruit quality, and fruit production (Jamiez et al., 2000), several irrigation frequencies adopted in previous studies have shown inconsistent trends for site-specific conditions (Sammis, 1980; Ellis et al., 1986; Caldwell et al., 1994; El-Gindy and El-Araby, 1996; Hanson et al., 2003).

On the other hand, studies have shown that mulch could play an important role in irrigation water management and crop production by modifying plant environment (Qin et al., 2015; Wang et al., 2015). This is attributed to the ability of mulch materials to conserve soil moisture where water resources are scarce, especially in dry humid environments (Wani et al., 2006; Solaiman et al., 2008; Adekiya et al., 2017; Smith, 2017). Wani et al. (2006) explained that mulching retards loss of moisture from soil, and as a result, higher and uniform soil moisture regimes are maintained. Furthermore, several studies have demonstrated the impact of mulch types on soil properties and crop yield (Monks et al., 1997; Doring et al., 2005; Kar and Kumar, 2007; Aiyelari et al., 2011; Norman et al., 2011; Dauda, 2012). Among these, the suitability of grass mulches over legume mulches in reducing soil temperature and enhancing soil moisture and crop yield in dry season conditions has been reported (Agele et al., 2010; Adekiya et al., 2017; Smith, 2017). Notably, *Pennisetum purpureum* has been averred a superior mulch material to *Pueraria phaseoloides and Mucuna pruriens* in improving crop yield in dry cropping season conditions (Adekiya et al., 2017), while its combination

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Table 1. Baseline properties of the soil prior to cropping.

Parameter	Year 1	Year 2
pH (1:1 $^{w}/_{v}$, soil:H_2O)	6.8	5.6
Organic carbon (g kg^{-1})	46.6	45.2
Total nitrogen (g kg^{-1})	0.6	0.5
Available P (mg kg^{-1})	47.49	46.42
Exchangeable bases (cmol kg^{-1})		
Ca	21.93	20.88
K	0.68	0.63
Na	1.13	1.08
Exchangeable acidity (cmol kg^{-1})	2.50	2.27
Cu (mg kg^{-1})	13.3	12.20
Mn (mg kg^{-1})	65.7	64.22
Fe (mg kg^{-1})	74.2	73.05
Particle size distribution (g kg^{-1})		
Sand	858	849
Silt	54	61
Clay	88	90
Textural class	Loamy sand	Loamy sand

with poultry litter has also improved potato production (Yagi et al., 2020). Contrariwise, the use of *Pennisetum purpureum* was also associated with low crop yield relative to other mulch materials (Smith, 2017). Though these studies (Adekiya et al., 2017; Smith, 2017; Sadek et al., 2019; Yagi et al., 2020) focused solely on the response of crops (*Abelmoschus esculentus*, *Solanum tuberosum*, *Cucumis melo*) to mulch without considering the effects of irrigation frequencies, these variations could be attributed to differences in soil moisture conditions.

Tomato is one of the most important vegetables grown throughout the world. It is regarded as the second most consumed vegetable after potato (Suresh et al., 2014). In Nigeria, tomato is largely cultivated in the North under irrigated farming systems. While it can be grown almost throughout the year (Kundu et al., 2019), its yield is directly affected by water deficit resulting from scarce rainfall and high soil evapotranspiration rates (Byari and Al-Sayed, 1999) which affect superficial and underground sources of water supply. This scenario is further worsened by the inability of resource poor farmers to afford irrigation during periods of rainfall scarcity due to unavailability and/or high cost of irrigation facilities in many areas. Hence, mulching is widely adopted to provide the benefits of sustaining crop growth and yield by complementing irrigation. Whilst Maida and Kumar (2020) examined the combined effect of mulch and irrigation schedule on the performance of chilli, the yield

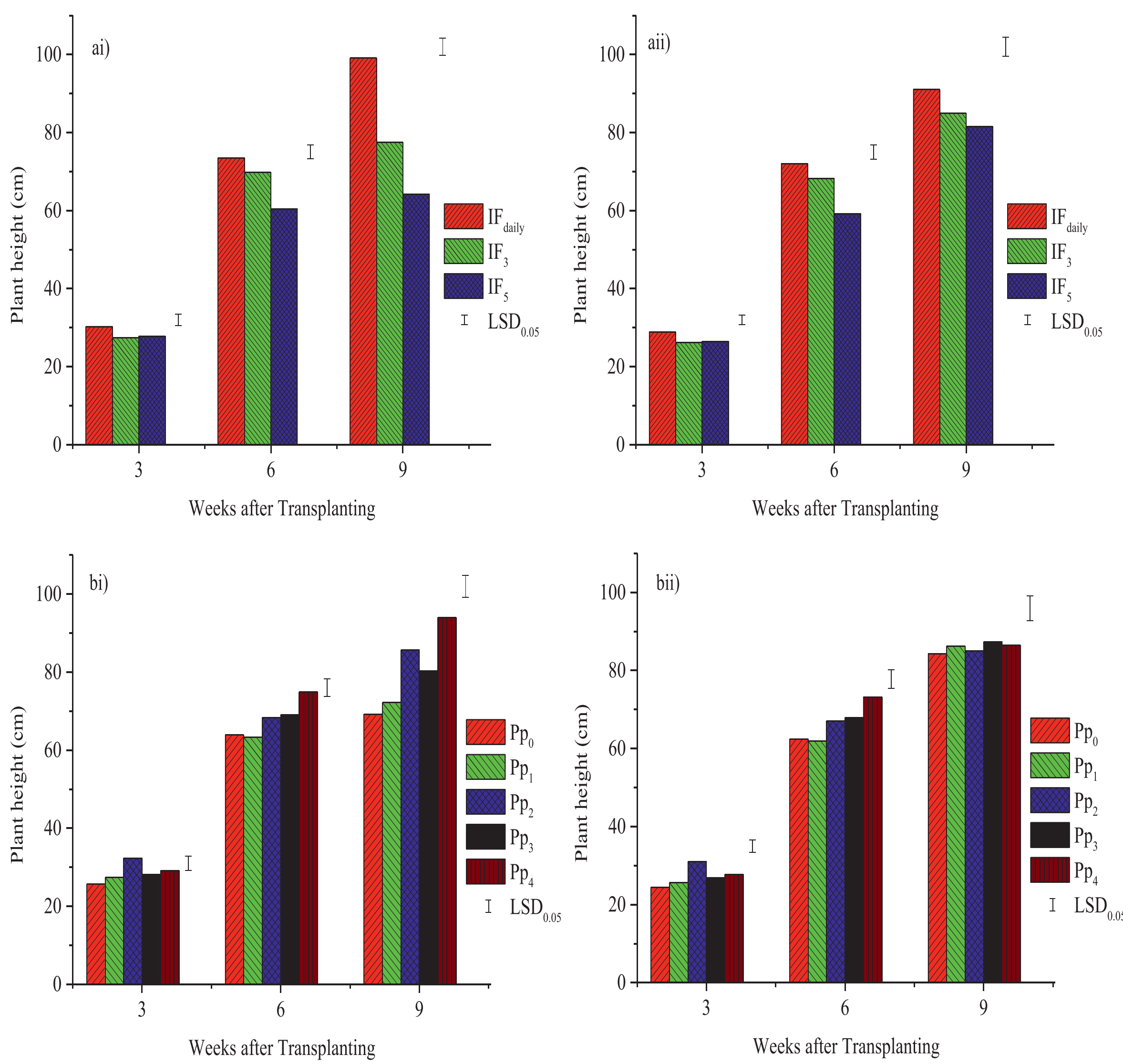

Figure 1. Tomato plant height as influenced by (a) irrigation frequencies and (b) mulch application in (i)year 1 and (ii) year 2.

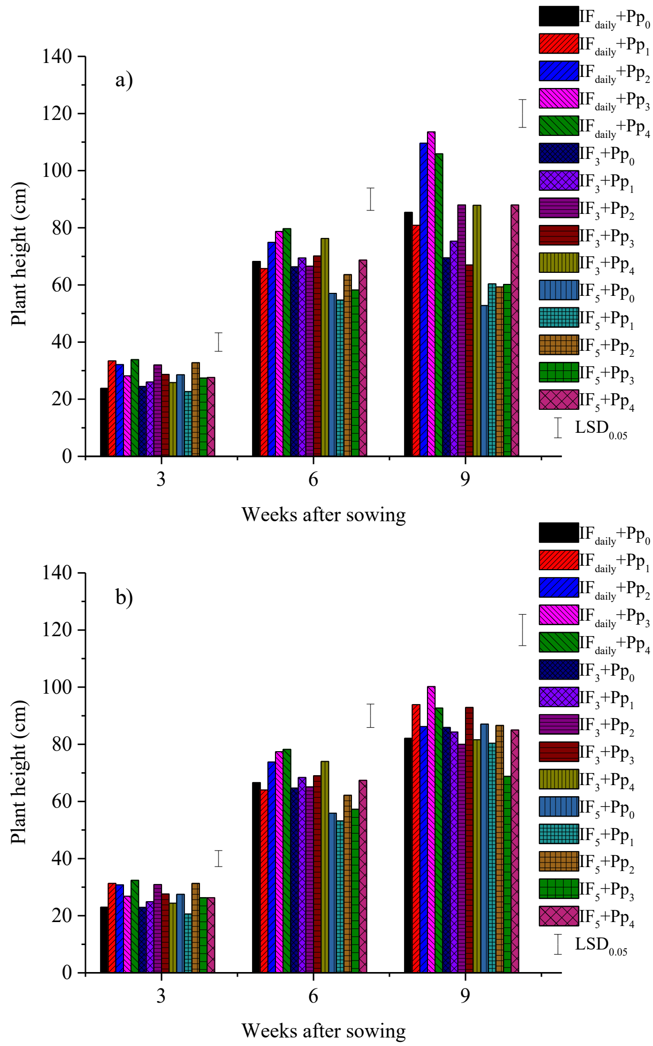

Figure 2. Response of tomato plant height to irrigation frequencies × mulch interaction in (a) year 1 and (b) year 2.

response of tomato to irrigation frequency and mulch effects is yet to be examined. This study therefore investigates the effects of mulch application on the growth and yield of tomato under different irrigation frequencies.

2. Materials and methods

2.1. Experimental site

The study was conducted in 2015 (Year 1) and repeated with the same settings in 2016 (Year 2) in the screenhouse (Latitude 07° 27′ 06.4″ N and Longitude 03° 53′ 46.1″ E) of the Department of Agronomy, University of Ibadan, Nigeria. The average minimum and maximum temperature of the screenhouse were 20 °C and 30 °C respectively, during the study. The soil used for the experiment was obtained from the Teaching and Research Farm of University of Ibadan, Nigeria. The farm has been cultivated to maize and vegetable for several decades. The soil is an Alfisol formed on a Granite Gneiss parent material and classified as a Typic kandiustalf. It is locally classified as Ibadan series (Smyth and Montgomery, 1962). Soil samples were randomly collected at 0–30 cm and homogenised before taken to the laboratory for routine analyses using standard procedures. The baseline status of the chemical properties and particle size distribution of the soil are presented in Table 1. The soil organic carbon was 46.6 g k^{-1} and 45.2 g k^{-1} in years 1 and 2 respectively, while corresponding values for total nitrogen were 0.6 g k^{-1} and 0.5 g kg^{-1}, respectively. The soil pH was acidic in both years of the study but was higher in year 1 relative to year 2. The textural class of the soil was loamy sand with marked high sand content in year 1 (858 g kg^{-1}) and year 2 (849 g kg^{-1}).

2.2. Experimental setup and design

Tomato (*Roma* variety) seeds obtained from the National Institute for Horticultural Research (NIHORT), Ibadan, Nigeria were raised in a nursery for three weeks and transplanted into 10 kg capacity experimental pots, with a surface area of 1.77 m^2, containing 5 kg composite soil in two trials. The seedlings were subjected to three irrigation frequencies (IF): daily irrigation (IF_{daily}), irrigation at 3-days interval (IF_3) and irrigation at 5-days interval (IF_5). The irrigation source was a well situated at the study site, and each pot was irrigated to 100% field capacity (≈176, 919.39 mm^3 daily irrigation) at each interval using a traditional bucket (5 L capacity) system of irrigation. *Pennisetum purpureum* (Pp) leaves obtained from the study site were chopped to 5 cm length before spreading on the soil surface at 1 t ha^{-1} (Pp_1), 2 t ha^{-1} (Pp_2), 3 t ha^{-1} (Pp_3) and 4 t ha^{-1} (Pp_4) and compared against a bare soil as control (Pp_0). The treatments were arranged as a 3 × 5 factorial in completely randomised design with four replicates.

2.3. Data collection

Data on growth parameters such as number of leaves, plant height (cm) and stem diameter (mm) were measured by count, metre rule and a digital vernier caliper at 3, 6 and 9 weeks after transplanting (WAT) respectively, while yield parameters such as number of fruits and fresh fruit weight were measured at harvest using standard procedures.

2.4. Statistical analyses

Data were analysed using the General linear model procedure of GenStat Discovery Statistical Package (8th Edition). Data were subjected to descriptive statistics and two-way analysis of variance at 5% probability level, while significantly different means were grouped by Fisher's Least Significant Difference (LSD) at 5% level of probability. Simple linear regression analysis was also performed on the yield parameters to ascertain the contribution of mulch to tomato yield under the various irrigation frequencies.

3. Results and discussion

3.1. Effects of irrigation frequency and mulch on tomato growth

The total volume of water distributed per plant during the crop cycle was 15, 922, 745.1 mm^3 for 90 days of irrigation in IF_{daily}, and this reduced by 66.7% for 30 days of irrigation in IF_3 and 80.0% for 18 days of irrigation in IF_5. Figure 1 presents the height of tomato plants as influenced by irrigation frequencies and mulch rates in years 1 and 2. The difference in tomato height across irrigation frequencies was significant in both years of cropping. In year 1, it was lower in IF_3 (10.5%–27.8%) and IF_5 (8.9%–54.5%) than the control (IF_{daily}) (Figure 1ai). Similarly, corresponding values of 7.2%–10.4% (IF_3) and 9.3%–11.6% (IF_5) reduction were observed relative to IF_{daily} in year 2 (Figure 1aii). Among mulch rates, tomato height was clearly enhanced at 3–9 WAT in both years of the study. In year 1, the tallest plant was obtained in Pp_4 (97.9 cm), followed by Pp_2 (85.63 cm) at 9 WAT (Figure 1bi). Though Pp_3 produced the tallest plants (87.3 cm) at 9 WAT in year 2, it was comparable with other mulch rates (Figure 1bii). Although the plant height of tomato was superior in IF_{daily} + Pp_3, it was statistically at par with IF_{daily} + Pp_4 at 6 WAT and 9 WAT in both years of the study. Furthermore, IF_{daily} + Pp_4 was also similar to IF_3+Pp_4 and IF_3+Pp_3 in both years of the study (Figures 2a and 2b).

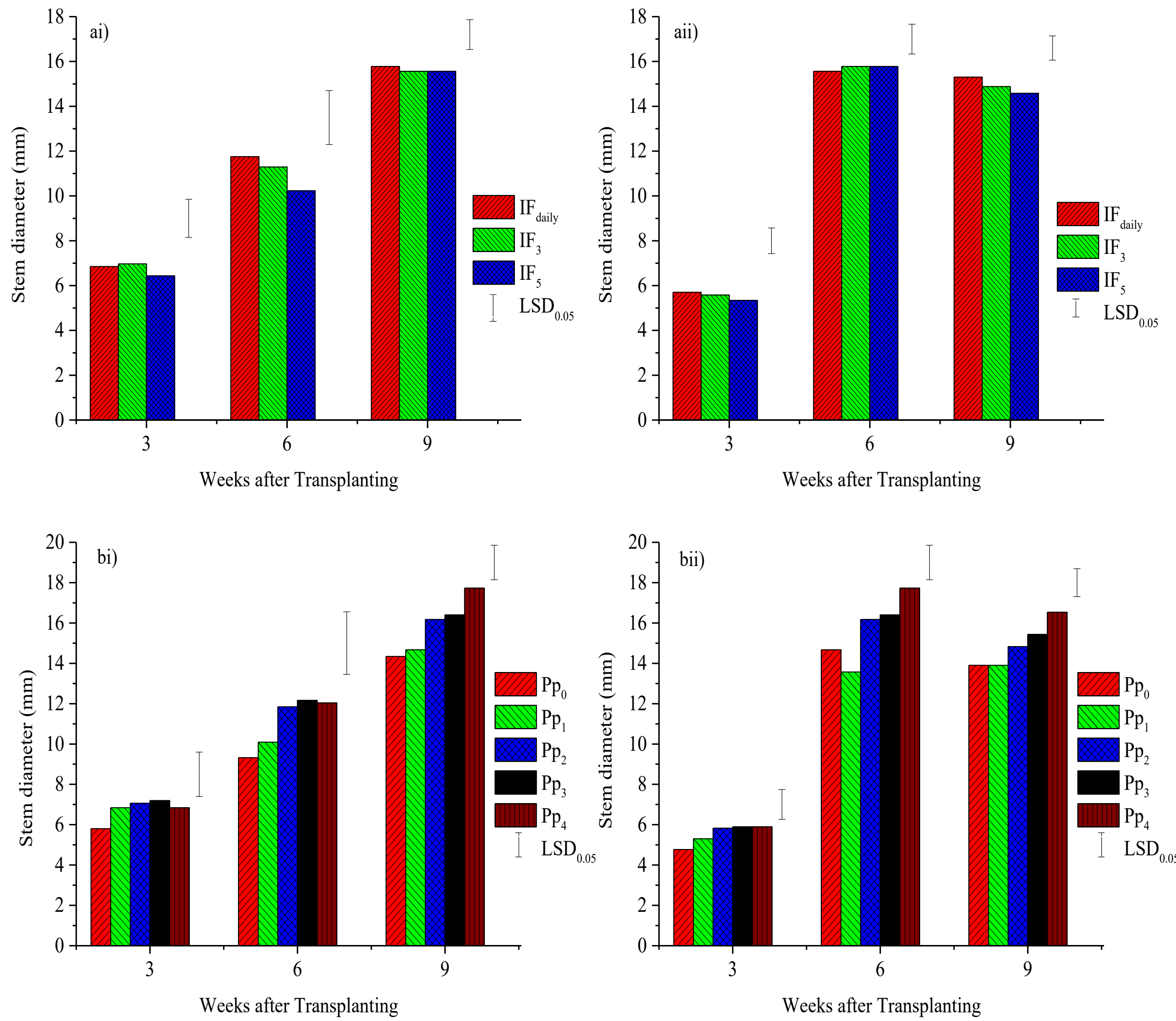

Figure 3. Effects of (a) irrigation frequencies and (b) mulch application on tomato stem diameter in (i) year 1 and (ii) year 2.

The effects of irrigation frequencies and mulch application rates on the stem diameter of tomato in both years of study are presented in Figure 3. Stem diameter only differed significantly among the irrigation frequencies at 6 WAT. Our results showed that peak values obtained at 9 WAT were reduced by 1.4% in IF_3 and IF_5 relative to IF_{daily} in year 1 (Figure 3ai). In year 2, stem diameter only differed significantly among the irrigation frequencies at 9 WAT and was lower in IF_3 and IF_5 by 2.8% and 4.9% compared with IF_{daily}, respectively (Figure 3aii). Among mulch rates, stem diameter differed significantly and was in the order of $Pp_4 > Pp_3 > Pp_2 > Pp_1 > Pp_0$ in years 1 and 2, respectively (Figure 3bi and bii). However, Pp_1 was similar to Pp_0 in years 1 and 2, respectively. In addition, stem diameter was consistently superior at 6 and 9 WAT in $IF_3 + Pp_4$ but did not differ significantly from $IF_{daily} + Pp_4$ and $IF_{daily} + Pp_3$ in both years of study (Figures 4a and 4b).

Figure 5 presents the effects of irrigation frequencies and mulch rates on the number of leaves of tomato. The number of tomato leaves produced across irrigation frequencies differed significantly at 6 and 9 WAT in year 1 (Figure 5ai). In comparison, the peak values at 9 WAT were lower in IF_3 (by 6.7%) and IF_5 (by 8.7%) than with the IF_{daily}. In year 2, reduction in irrigation frequency significantly increased tomato leaf production at 6 and 9 WAT (Figure 5aii). Relatively, number of leaves was higher in IF_3 than IF_{daily} and IF_5 by 11.9% and 15.3%, respectively. Regarding mulch rates, number of leaves was evidently increased at 6 and 9 WAT in both years. In year 1, number of leaves was in the order: $Pp_4 > Pp_3 > Pp_2 > Pp_1 > Pp_0$ at 9 WAT (Figure 5bi). In year 2, Pp_3 and Pp_1 were superior to the other rates, having the highest increase (10.7%) in number of leaves compared with the Pp_0 (Figure 5bii). Contrariwise, Pp_4 gave the lowest increase in the number of tomato leaves produced (8.1%) relative to Pp_0. Among the combinations, $IF_5 + Pp_0$ and $IF_{daily} + Pp_0$ were dominant in enhancing the vegetative growth of tomato, and were comparable with $IF_3 + Pp_4$, $IF_3 + Pp_3$, $IF_5 + Pp_2$, $IF_{daily} + Pp_3$ and $IF_3 + Pp_2$ in both years, respectively (Figures 6a and 6b).

The superior number of leaves in irrigation frequency of 3-days interval relative to daily irrigation (in year 2) could be attributed to a balanced soil water and air ratio in the 3-days irrigation interval which could have enhanced high root respiration and vegetative growth relative to daily irrigation. This result is corroborated by those of earlier studies (Aujla et al., 2005; Panigrahi and Sahu, 2013). However, contrary findings of increase in number of leaves with increase in irrigation levels have been reported (Aujla et al., 2005; Abd El-Kader et al., 2010). The reduced growth in 5-days irrigation interval might have ensued from occasional water stress conditions that could have inhibited tomato growth by lowering its metabolic activities especially at crucial stages of the plant's phenology. Low crop growth resulting from infrequent irrigation and low irrigation water level has also been reported by several authors (Hegde, 1989; Sepaskhah and Kamgar Haghighi, 1997; Rashidi

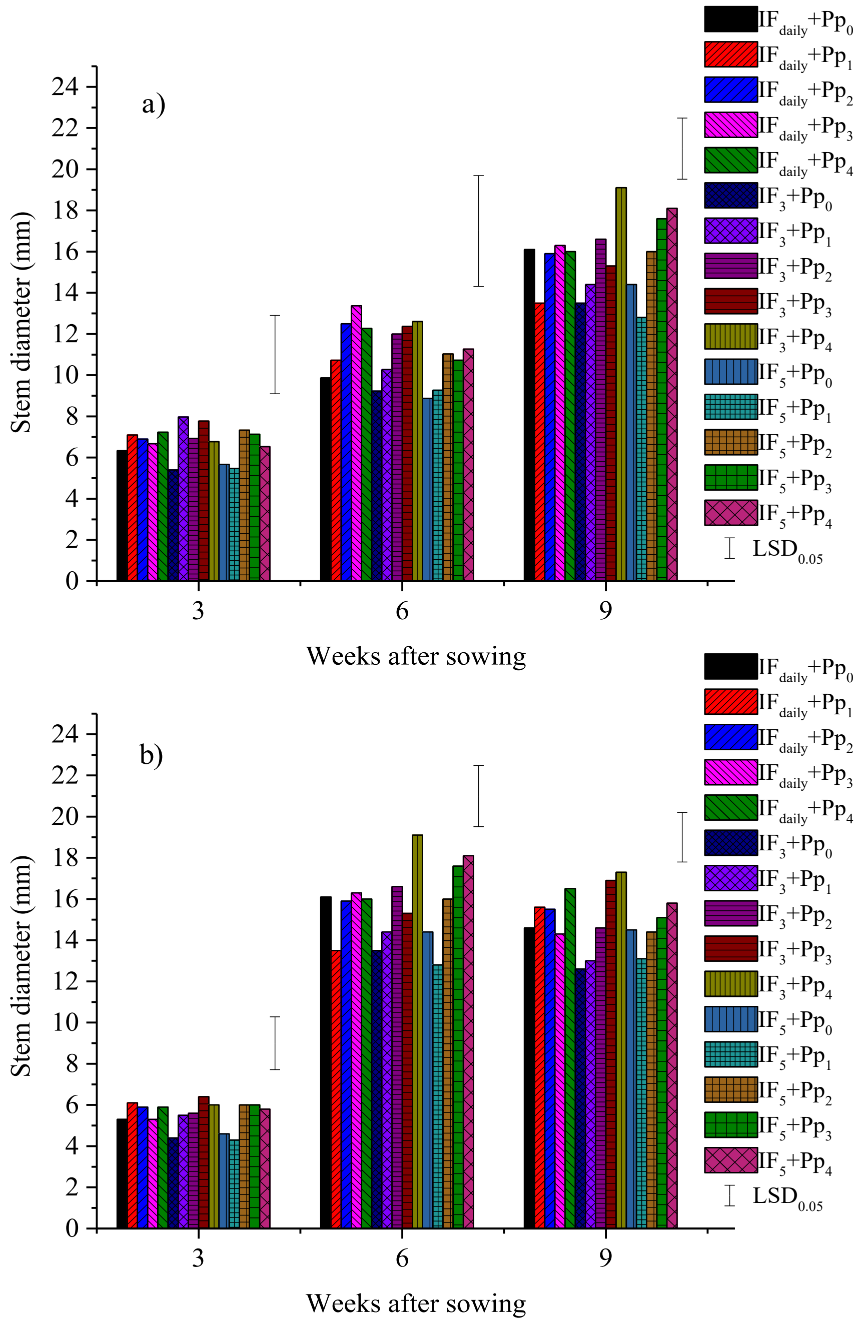

Figure 4. Stem diameter of tomato as influenced by irrigation frequencies and mulch combinations in (a) year 1 and (b) year 2.

and Keshavarzpour, 2011; Panigrahi and Sahu, 2013). Panigrahi and Sahu (2013) explained that superior vegetative growth in high irrigation level was probably caused by increased metabolic activity of plants due to high available moisture in the root zone. This suggests that withdrawing irrigation for 5 days could adversely affect tomato growth. Generally, the magnitude of difference between tomato growth indices under daily irrigation and 3-days interval was little.

The higher plant height, stem diameter and number of leaves obtained for mulched plants compared to unmulched plants could be ascribed to improved topsoil temperature (not measured) under mulching which aids seed germination, root growth and plant development (Chen et al., 2007; Zhang et al., 2009; Siczek et al., 2015). This was also reported in earlier studies (Iftikhar et al., 2011; Norman et al., 2011). Several studies have shown among the benefits provided by mulch, that the reduction in rate of soil moisture loss, and the alteration in soil temperature are two of the most important benefits that could greatly affect crop growth (Li et al., 2004; Bu et al., 2013; Montenegro et al., 2013; Zhu et al., 2015). The higher plant height, stem diameter and number of leaves in 4 t ha^{-1} and 3 t ha^{-1} mulch relative to 2 t ha^{-1} and 1 t ha^{-1} showed increase in mulch effects with higher application rates. This suggests that higher rates of mulch application provided a more favourable environment for efficient use of available water for crop growth. It is important to note that mulch application at 3 t ha^{-1} was comparable to 4 t ha^{-1} and was higher for plant height and number of leaves in year 2, respectively. The dominant growth of tomato in IF_{daily} + Pp_4, IF_{daily} + Pp_3, IF_3+Pp_4 and IF_3+Pp_3 might be attributed to high level of available moisture resulting from frequent irrigation and moisture conservation by the mulch rates, while the observed variations in tomato growth among the treatments may be due to environmental factors (not measured) causing varying responses to irrigation and mulch application.

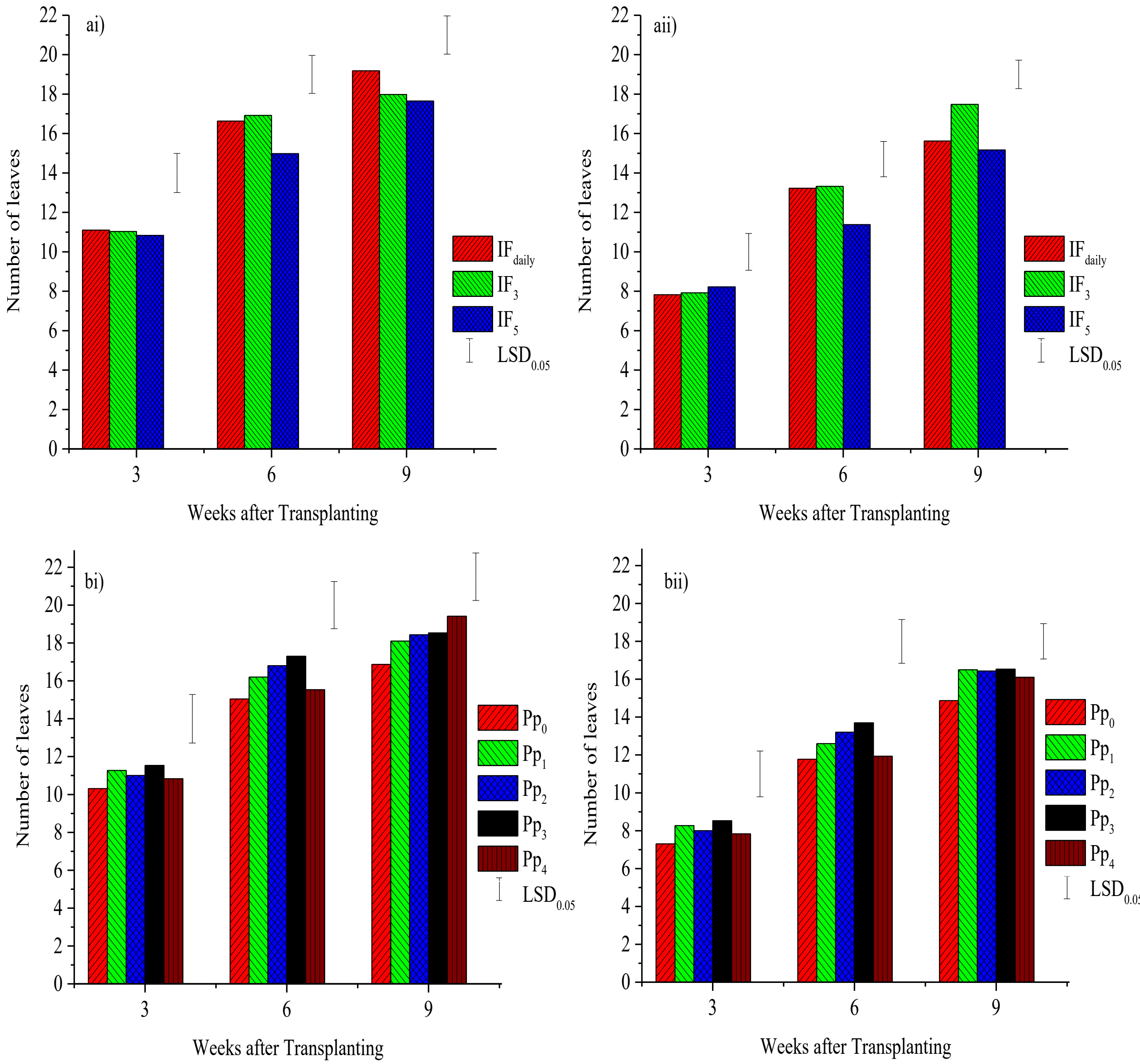

Figure 5. Effects of (a) irrigation frequencies and (b) mulch application on number of leaves of tomato in (i) year 1 and (ii) year 2.

3.2. Tomato yield as influenced by irrigation frequency and mulch

Table 2 presents the effects of irrigation frequencies and mulch rates on the number of fruits and fresh fruit weight of tomato in years 1 and 2, respectively. There was no significant difference in the number of tomato fruits produced among the irrigation frequencies in year 1. Plants in IF_3 produced higher number of fruits than IF_{daily} (by 3.1%) and IF_5 (by 13.8%). In year 2, the number of fruits in IF_{daily} and IF_3 were similar and distinctly higher than IF_5 by 63.6% and 54.6%, respectively. On the other hand, mulch rates significantly increased the number of tomato fruits produced in both years of the study. In year 1, Pp_4 and Pp_3 increased number of fruits by 50.0% and 42.3% compared with Pp_0, respectively. However, number of fruits in Pp_2, Pp_1 and Pp_0 were statistically at par. Similarly, Pp_4 had the highest number of fruits in year 2, but it was comparable to Pp_2 and Pp_3. The number of fruits in Pp_1 did not differ significantly from that obtained in Pp_0. In general, the interaction between irrigation frequencies and mulch rates significantly influenced number of fruits in year 1 and year 2 (Table 2).

The effects of irrigation frequencies and mulch rates on the fresh fruit weight of tomato in years 1 and 2 are presented in Table 2. Irrigation frequencies had significant effect on the fresh fruit weight of tomato in both years, respectively. For instance, fresh fruit weight was higher by 53.6% and 86.2% in IFd_{aily} than IF_3 and IF_5, respectively in year 1. Corresponding values for year 2 were higher by 26.6% and 65.0% in IF_3 and IF_5 compared with IFd_{aily}. Among mulch rates, significant increase in fresh fruit weight was recorded in years 1 and 2, respectively. In comparison with the control, the highest increase in fresh fruit weight was recorded in Pp_4 (107.5%), followed by Pp_3 (99.9%) and least by Pp_2 (30.2%) in year 1. It is worthy to note that Pp_2, Pp_1 and Pp_0 were similar in year 1. Results obtained in year 2 showed strong trend in increase in fresh fruit weight with corresponding increase in mulch rate. Increase in fresh fruit weight was in the order: Pp_4 (215.3%) > Pp_3 (125.2%) > Pp_2 (104.2%) > Pp_1 (84.1%). In addition, the fresh fruit weight of tomato was significantly influenced by the interaction between irrigation frequencies and mulch rates in both years of the study (Table 2). In comparison, the combination of irrigation frequencies and mulch rates resulted in superior yield relative to their individual effects. The highest tomato yield was obtained in IF_{daily} + IF_4 which was comparable with that obtained in IF_3+IF_4 in both years of the study.

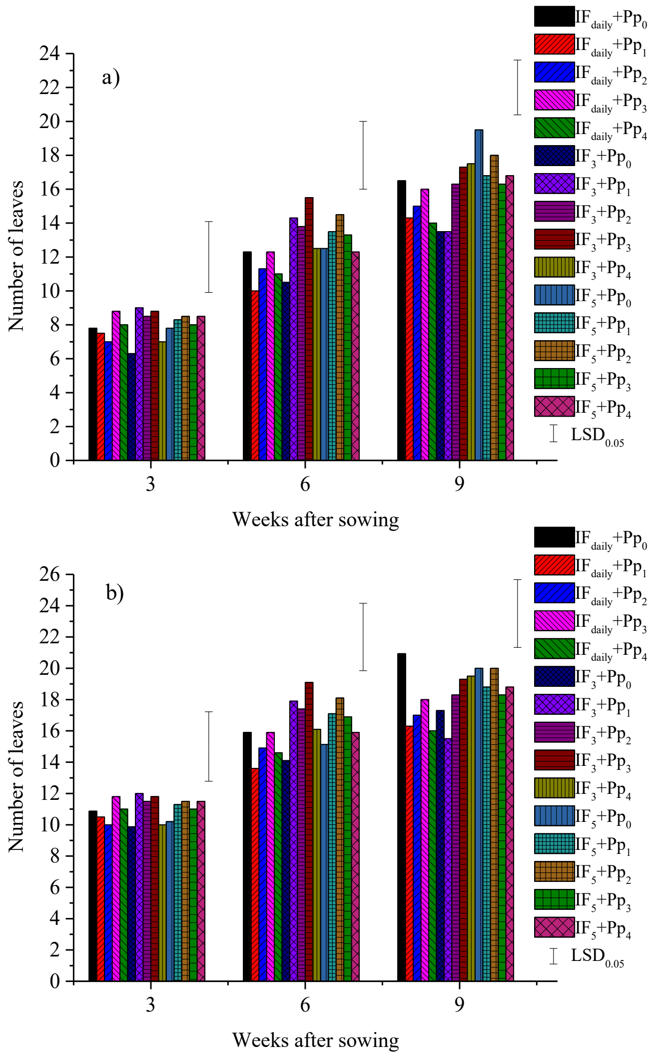

Figure 6. Number of leaves of tomato as affected by irrigation frequencies and mulch combinations in (a) year 1 and (b) year 2.

Table 2. Tomato yield as influenced by irrigation frequencies and mulch application rates.

		No. of fruits (ha^{-1})		Fresh fruit weight ($t\ ha^{-1}$)	
		Year 1	Year 2	Year 1	Year 2
†Irrigation Frequency (IF)					
IF_{daily}		32000.0	36000.0	0.18	0.09
IF_3		33000.0	34000.0	0.12	0.07
IF_5		29000.0	22000.0	0.10	0.05
$LSD_{0.05}$		ns	4371.63	0.02	0.01
†Mulch ($t\ ha^{-1}$)					
Pp_0		26000.0	17000.0	0.08	0.03
Pp_1		28000.0	23000.0	0.12	0.06
Pp_2		29000.0	37000.0	0.11	0.07
Pp_3		37000.0	30000.0	0.16	0.08
Pp_4		39000.0	47000.0	0.17	0.11
$LSD_{0.05}$		3777.12	3559.03	0.01	0.01
Irrigation Frequency × Mulch					
IF_{daily}	Pp_0	25000.0	20000.0	0.12	0.04
	Pp_1	28000.0	20000.0	0.13	0.08
	Pp_2	29000.0	40000.0	0.16	0.09
	Pp_3	44000.0	40000.0	0.24	0.08
	Pp_4	40000.0	60000.0	0.24	0.14
IF_3	Pp_0	27000.0	20000.0	0.06	0.04
	Pp_1	31000.0	30000.0	0.81	0.06
	Pp_2	32000.0	40000.0	0.11	0.06
	Pp_3	27000.0	30000.0	0.13	0.07
	Pp_4	40000.0	50000.0	0.20	0.10
IF_5	Pp_0	26000.0	10000.0	0.07	0.02
	Pp_1	27000.0	20000.0	0.14	0.04
	Pp_2	27000.0	30000.0	0.05	0.05
	Pp_3	30000.0	20000.0	0.14	0.07
	Pp_4	37000.0	30000.0	0.08	0.08
$LSD_{0.05}$		5033.22	5992.59	0.02	0.01

Subscripts are irrigation frequencies (in days) and mulch rates (tonnes per hectare), respectively; Pp = *Pennisetum purpureum*; LSD = Least significant difference; ns = means in the same column under the same category are not significantly different at $p \leq 0.05$.

Considering tomato fruit production, irrigation at 3-days interval proved superior to daily irrigation in producing higher number of fruits. Due to inhibited growth, tomato plants irrigated at 5-days interval had fewer number of fruits and lower fresh fruit weight relative to the others. This might have emanated from water stress which affects crop growth and yield. Besides the infrequent amount of water supply in 5-days irrigation interval, the low moisture storage capacity of the soil (coarse texture) could have further contributed to the low yield as substantial percolation below the plant's root zone was observed during the experiment. This suggests that 5-days irrigation frequency may not be feasible for high marketable yield production in irrigated tomato farming. Similar result was obtained by Hanson et al. (2003) who reported low tomato yield in low irrigation frequency. The superior number of fruits produced in 3-days irrigation interval did not translate to superior fresh fruit weight when compared to daily irrigation. This suggests that the response of tomato for number of fruits produced could be different from fresh fruit weight. Thus, while 3-days irrigation interval could cause rapid fruit production, daily irrigation could delay fruit production by allotting more time for fruit development, thereby resulting to bigger fruits. The reduced fresh fruit weight in 3-days and 5-days irrigation intervals could also be attributed to the disparity between soil available water and evapotranspiration, which results in an imbalance between water supply in soils and crop water requirement (Huang et al., 2005; Zhang et al., 2009). Similar observations of higher yield in cucumber and tomato have also been recorded in daily irrigations relative to lower irrigation intervals (El-Gindy and El-Araby, 1996; Hanson et al., 2003). However, tomato yield production in 3-days irrigation interval can be enhanced by mulching instead of embarking on daily irrigation. This is because available water for irrigation is increasingly becoming scarce in most parts of the world (Aliku, 2017). Therefore, management approaches should be taken to reduce daily irrigation and adopt sustainable practices that would enhance soil available water for plant use.

The superior number of fruits and fresh fruit weight obtained in mulched plants might be attributed to the contributions of *Pennisetum purpureum* to soil organic matter and soil nutrient status (Bationo and Buerkert, 2001; Lal, 2004; Bationo et al., 2007; Liu et al., 2009; Naab et al., 2015; Wang et al., 2016). The superior yield increase obtained in Pp_4 (average of 161.4%) and Pp_3 (average of 112.6%) over two years of cropping could be due to superior soil moisture (not reported) for plant use in mulch treatments. This result is corroborated by the observations in previous studies (Gao et al., 2009; Hai et al., 2015) where increase in soil moisture was attributed to large quantities of mulch application. This has been shown to increase crop yield in dryland farming (Passioura, 2006; Vohland and Barry, 2009). Though results from this study suggests increase mulch rate corresponds to increase in tomato yield production, Pp_4 was comparable to Pp_3. Hence, Pp_3 could be sufficient for high tomato yield under the prevailing weather conditions, relative to Pp_4. Several studies have shown that the increase in crop yield in mulched

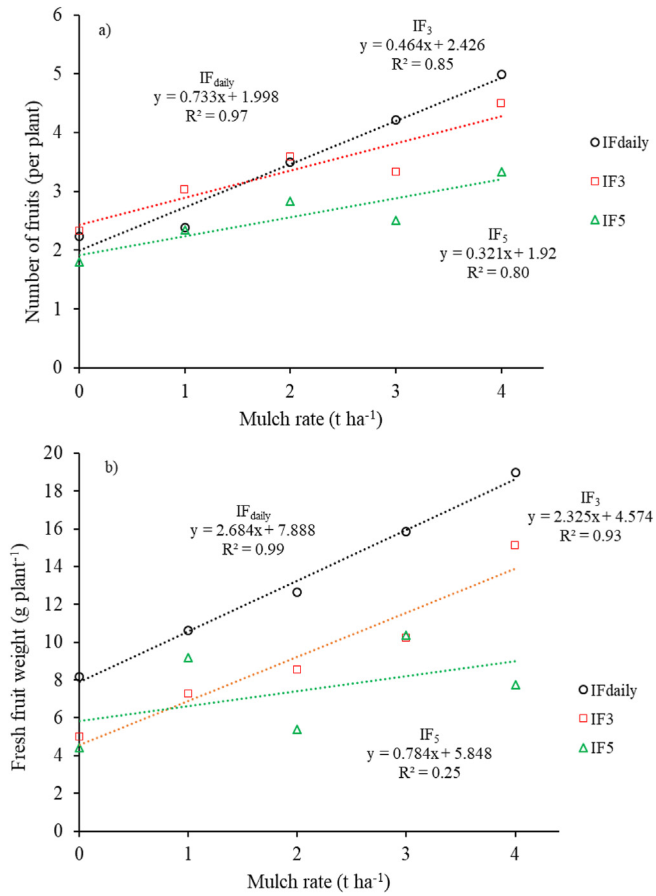

Figure 7. Relationship of (a) number of fruits, (b) fresh fruit weight of tomato with mulch under three irrigation frequencies.

plots could be attributed to reduced soil moisture loss via evaporation, thus leading to enhanced irrigation water use efficiency and yield production (Ramalan and Nwokeocha, 2000; Xie et al., 2005; Chakraborty et al., 2008; Zhou et al., 2009; Jemai et al., 2013; Awe et al., 2015; Li et al., 2015). Our study showed that the combination of IF_3+Pp_4 could be adequate for maintaining adequate ratio of soil moisture and soil aeration for high fresh fruit yield of tomato relative to the other treatment combinations. It should however be noted that Pp_1 and Pp_2 did not amount to significant increase in tomato yield production relative to unmulched plants. This could be due to the inability of Pp_1 and Pp_2 to provide sufficient ground cover for reduction in the rate of evaporation, and consequently cool the topsoil for improved tomato growth and yield production. It could be inferred that the plant environment in Pp_1 and Pp_2 did not differ significantly from the unmulched pots.

3.3. Relationship between tomato yield and mulch rates as influenced by irrigation frequencies

The percentage contribution of *Pennisetum purpureum* mulch to tomato yield under the different frequencies of irrigation is presented in Figure 7. The contribution of *Pennisetum purpureum* mulch to tomato yield decreased with decrease in irrigation frequency. Our results showed that mulch significantly ($p < 0.05$) contributed 97.0%, 85.0% and 80.0% to the variation in number of fruits produced in daily irrigation, 3-days irrigation interval, and 5-days irrigation interval, respectively (Figure 7a). Corresponding values for fresh fruit weight were 99.0%, 93.0% and 25.0% for daily irrigation, 3-days irrigation interval, and 5-days irrigation interval, respectively (Figure 7b). The observed significant linear relationship between tomato yield and mulch application under the different irrigation frequencies suggests an increase in mulch application with increase in irrigation could bring about a corresponding increase in yield. This is corroborated by the higher yield results obtained in tomato plants given higher number of irrigations in Kundu et al. (2019) relative to our study.

4. Conclusion

Our results show that irrigation frequency significantly influenced crop growth and yield. While reduction in irrigation frequency reduced fresh fruit weight of tomato, irrigation at 3-days interval was comparable to daily irrigation. However, irrigation at 5-days interval caused substantial reduction in tomato yield. There was marked improvement in tomato yield following mulch application, and the application of Pp_3 appeared promising in improving tomato yield over the two-year period. In general, the contributions of irrigation and mulch combination to improving tomato yield exceeded those of their individual application, and IF_3+Pp_4 was not substantially different from IF_{daily} + Pp4, thus appearing most effective for irrigation water management and improvement of tomato yield. Therefore, combining irrigation at 3 days interval and *Pennisetum purpureum* mulch at 4 t ha^{-1} could provide an additive effect for water management and tomato yield.

Declarations

Author contribution statement

E. A. Aiyelari, S. O. Oshunsanya, O. Aliku, S. A. Adeniran, M. Ona: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Additional information

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