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Intra-Row Spacing and Pruning Effects on Fresh Tomato Yield in Sudan Savanna of Nigeria

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Abstract: Two field trials were conducted during 2004/05 and 2005/06 dry season under irrigation at the Usmanu Danfodiyo University, Fadama Teaching and Research Farm, Sokoto in order to evaluate the effects of intra-row spacing and pruning on Roma VFN cultivar of tomato. The treatments consisted of factorial combination of two training (Staked and unstaked), three intra-row spacings (20, 40 and 60 cm) and three pruning levels (three-stem, two-stem and unpruned) laid out in a split-plot design replicated three times. Training was allocated to the main plots while spacing and pruning were allocated to the sub plots. This paper presents the results on spacing and pruning effects. Results showed that mean fruit length and diameter was significantly ($p<0.05$) higher in 60 cm spaced plants than 20 and 40 cm and two to three stem pruned plants recorded higher fruit length and diameter. Highest total fresh fruit yield was obtained at closer (20-40 cm) intra-row spacing. Pruning reduced number of marketable fruits per plant and increased the weight of marketable fruits per plant. Mean fruit weight was higher for 40 and 60 cm inter-row spacing and three-stem pruning while total fresh fruit yield was higher in 20-40 cm intra-row spacing and three stem pruning. Therefore it can be concluded from this study that pruning of tomato could be practiced to increase the yield and quality of tomato. An intra-row spacing of 20-40 cm was appropriate for maximum fresh tomato yield and quality. Three-stem pruning coupled with closer intra-row spacing (20-40 cm) may be recommended for higher production of tomato variety (Roma VFN) in the Sudan savanna of Nigeria.

Key words: Tomato (*Lycopersicon lycopersicum* mill.), intra-row spacing, pruning, Sudan savanna, Nigeria

INTRODUCTION

Tomato (*Lycopersicon lycopersicum* Mill.) belongs to solanaceous group of fruit vegetables together with other related crops such as garden egg, peppers and potato. They are one of the most important vegetables in the northern part of Nigeria. They are relatively easy to grow and are an important source of nutrition and income for smallholders and large commercial producers. They are important source of vitamins and minerals and now the most widely grown vegetable crop in the world (Villareal, 1980). It can be used as a fresh vegetable and also processed and canned as a paste, sauce, ketchup and juice.

The world production of tomato was estimated at 70 million tonnes from 2.7 million hectares. Most of the produce is from temperate countries with little (11%) from tropical countries (Rafi, 1996). The average yields recorded are about 9.9 t ha^{-1} in Thailand, 8.8 t ha^{-1} in Phillippines, 15.6 t ha^{-1} in India, 25.3 t ha^{-1} in China, 52.8 t ha^{-1} in Japan and 63.6 t ha^{-1} in USA. In Africa, highest yield was

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obtained in South Africa (76.25 t ha^{-1}) and the least was from Angola (3.7 t ha^{-1}) (FAOSTAT, 2005). The average yield of tomato in Nigeria is about 7.0 t ha^{-1} (FAOSTAT, 2005) where, it is widely cultivated in Guinea Savanna in wet season and Sudan Savanna in the dry season through irrigation (Adelana, 1977).

Farmers in Nigeria obtained very low yield (7 t ha^{-1}) compared to global yields-a phenomenon that could be attributed to cultural practices adopted by the farmers. Tomato yield could be increased substantially through improved cultural practices. Two of such practices that greatly influence tomato yield are intra-row spacing and pruning. Rafi (1996), Myanmar (1999), Chen and Lal (1999) and Abdel-Al *et al*. (1962) recommended pruning as a practice that improves yield and quality of tomato.

Optimum spacing improves performance of tomato. It has been reported that while wider spacing increased mean fruit size, mean fruit weight and fruit weight per plant, closer spacing increased fruit number per plant and total fruit yield per hectare (Rawshan, 1996; Zhang, 1999; Rafi, 1996; Myanmar, 1999). According to Wuster and Nganga (1970), properly pruned and appropriately spaced plants produce larger, earlier and relatively reasonable fruit yield than non-pruned tomato of the same variety. Therefore, farmers need information on the beneficial effects of integrating proper spacing and appropriate pruning on performance of tomato. It is for this reason that a trial was conducted to find out the optimum plant spacing and suitable pruning level for high yield of irrigated tomato in the Sudan savanna of Nigeria.

MATERIALS AND METHODS

Field experiments were conducted during the 2004/05 and 2005/06 dry seasons at the Usmanu Danfodiyo University, Fadama Teaching and Research Farm, Sokoto (latitude 13°09'N and longitude 05°5'E) (Kowal and Knabe, 1972). The climate of the area is semi-arid with rainfall range of 550-660 mm per annum, spread over a period of 4-5 months (May-September). A mean monthly temperature range of between 14-41°C was recorded between 2003-2006. The soil of the study area was clay loam (pH 5.7) and seasonally flooded (during rainy season). The physico-chemical analysis of the soil at the experimental site revealed that the soils were low in total N, available P and organic carbon and was slightly acidic in nature (pH = 5.61-6.35). The soil at the experimental site was loamy in 2004/05 and clay loam in 2005/06 cropping season (Table 1).

The treatments consisted of factorial combination of two training (staked and unstaked), three intra-row spacings (20, 40 and 60 cm) and three pruning levels (three-stem, two-stem and unpruned) laid out in a split plot design replicated three times. Training was allocated to the main plots while spacing and pruning were allocated to the sub plots. This paper presents only the results on spacing and pruning effects.

Table 1: Physico-chemical properties of the soil at the experimental site in 2004/05 and 2005/06 cropping season

Physical and chemical characteristics	2004/05	2005/06
Chemical properties		
pH (Water)	6.35	5.61
pH ($CaCl_2$)	5.92	5.56
Organic Carbon (g kg^{-1})	0.27	0.74
Total N (g kg^{-1})	0.056	0.77
Available P (PPM)	0.025	0.024
CEC (Cmol kg^{-1})	3.16	3.16
Exchangeable bases (Cmol kg^{-1})		
Ca	0.095	0.040
Mg	0.065	0.040
K	1.025	1.0505
Na	1.080	0.113
Physical properties		
Sand (g kg^{-1} soil)	442	338
Silt (g kg^{-1} soil)	444	350
Clay (g kg^{-1} soil)	114	312
Textural class	Loamy	Clay loam

Certified seed of tomato cultivar (Roma VFN) was obtained from Kebbi State Agricultural Supply Company (KASCOM) Birnin Kebbi. Seedlings were raised in nursery bed using nursery management techniques (Thinning out and hardening off was carried out before transplanting). Seedlings were transplanted at about 30-35 days after sowing (i.e., 4-5 leaf stage). Seedlings were planted at inter-row spacing of 50 cm and intra-row spacing of 20, 40 and 60 cm depending on the treatment. Stakes of about 1m length were driven at 10 cm to the side of the plants in the staked treatments. A strong but soft thread was used to tie the plants to the stake at intervals as the plant grows. Irrigation was done at an interval of between 4-7 days at field capacity. Fertilizer was split-applied at transplanting and 4 weeks after transplanting at the rate of 300 kg NPK (15:15:15) ha^{-1} and 140 kg Urea ha^{-1}, respectively.

Pruning was carried out from 4 WAT and continued 2-weekly up to 10WAT. Depending on the pruning level, one or two shoots just below the first flower cluster was left to grow as the second and third shoots, respectively, while the rest were removed. Weeds were controlled manually by weeding three times at 4 weeks interval. The plots were sprayed against insect at an interval of 3 weeks using Karate® (Lambdacyhalothrin) at 4 mL L^{-1} concentration. Fruits were harvested at regular intervals at physiological maturity (skin turned yellowish-orange).

Data was collected on mean fruit length, diameter and weight, total fresh fruit yield and percentage marketable yield. Data collected were subjected to analysis of variance procedure and significant differences were further analyzed using least significant difference test using SAS ®.

RESULTS AND DISCUSSION

Mean Fruit Length and Diameter

Mean fruit length and diameter was significantly ($p<0.05$) influenced by spacing in both trials and the two trials combined (Table 2). Results indicated that 60 cm intra-row spacing produced higher (6.19 cm for combined) fruit length than 40 (5.79 cm) and 20 cm intra-row spacing (5.45 cm) in both trials and in combined. Similarly, the highest mean fruit diameter was recorded in 60 cm (4.27 cm for combined) intra-row spacing than 40 and 20 cm intra-row spacing in the two trials and in the combined analysis. This trend is in conformity with Ahmad and Singh (2005) and could be attributed to the fact that wider spacings minimises competition for nutrients, water and radiation (Wesserman, 1985; Kochlar and Joseph, 1986). Further more, at wider spacing there is greater circulation of air and interception of light by the plants resulting in lower incidence of diseases and pests.

Table 2: Mean fruit length and diameter of tomato as influenced by intra-row spacing and pruning in 2004/05 and 2005/06 seasons and the two years combined

	Mean fruit length (cm)			Mean fruit diameter (cm)		
Treatments	2004/05	2005/06	Combined	2004/05	2005/06	Combined
Intra-row spacing (cm)						
20	5.32^c	5.28^c	5.45^c	3.45^c	3.43^b	3.54^c
40	6.02^b	5.56^b	5.79^a	4.23^b	3.53^b	3.93^b
60	6.83^a	5.88^a	6.19^a	4.87^a	3.98^a	4.27^a
SE	0.07	0.09	0.05	0.06	0.10	0.06
Sig.	S	S	S	S	S	S
Pruning						
Three-stem	6.26^a	5.64^{ab}	5.95^a	4.47^a	3.81^a	4.08^a
Two-stem	6.37^a	5.67^a	6.02^a	4.34^a	3.84^a	4.04^a
Unpruned	5.54^b	5.39^b	5.96^b	3.73^b	3.30^b	3.62^b
SE	0.07	0.09	0.05	0.06	0.10	0.06
Sig.	S	S	S	S	S	S
Interaction						
Spacing×Prun.	S	S	Ns	Ns	Ns	Ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD. Ns = Not significant; s = significant at 5% level of significance

Table 3: Number of marketable, unmarketable and total fruits per plant as affected by intra-row spacing and pruning in 2004/05 and 2005/06 cropping seasons

	Number of fruits per plant					
	2004/05			2005/06		
Treatments	MKT	UMKT	Total	MKT	UMKT	Total
Intra-row spacing (cm)						
20	21.44	9.17^{a}	30.61^{a}	21.06	8.44	29.50
40	21.33	8.17^{a}	29.50^{a}	20.89	8.11	29.00
60	21.56	6.61^{c}	28.17^{b}	21.22	8.33	29.56
SE	0.34	0.29	0.44	0.99	0.44	1.24
Sig.	Ns	S	S	Ns	Ns	Ns
Pruning						
Three-stem	21.11^{b}	8.00^{b}	29.11^{b}	20.28	8.33	28.61
Two-stem	17.17^{c}	6.17^{c}	23.33^{c}	21.39	8.44	29.83
Unpruned	26.06^{a}	9.78^{a}	35.83^{a}	21.50	8.11	29.61
SE	0.34	0.29	0.44	0.99	0.44	1.24
Sig.	S	S	S	Ns	Ns	Ns
Interaction						
Spacing×Prun.	Ns	Ns	Ns	Ns	Ns	Ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD. Ns = Not significant; s = significant at 5% level of significance, MKT = Marketable fruit, UMKT = Unmarketable fruits

Pruning had significant ($p<0.05$) effect on mean fruit length and diameter in both trials and the two trials combined (Table 2). Highest mean fruit length and diameter were obtained in three and two-stem pruned plants than unpruned plants in both trials separate and combined. This result agrees with the findings of Hernandez and Sanchez (1992), Zhang (1999) and Myanmar (1999). Pruning diverts nutrients to flower cluster and fruits on the main stem, Pruning improves air circulation within the canopy, which reduces foliar diseases and facilitates spraying and harvesting.

Number of Marketable Fruits Per Plant

Intra-row spacing significantly affected the number of unmarketable fruits and total number of fruits per plant in first trial (Table 3). Number of unmarketable fruits and total number of fruits per plant was significantly higher in 20 and 40 cm than 60 cm intra-row spacing. Spacing had no significant effect on the number of marketable fruits per plant in both trials. This result is in line with Zhang (1999) and Shuangxi (1985) who reported that spacing had no significant effect on both the number of marketable fruit per plant and the total fruits per plant. Higher fruits per plant in the close spacing plants could be as a result of higher competition for light and nutrient resulting in fruits that were many in number and were not of marketable size.

Pruning had significant effect on the number of marketable, unmarketable and total number of fruits per plant in the first trial while in the second trial there was no significant effect of pruning (Table 3). In the first trial, pruning resulted in significantly lower marketable, unmarketable and total number of fruits per plant than unpruned plants. More fruit number per plant in unpruned plants than pruned plants could be attributed to availability of more undisturbed fruit-producing shoots in the unpruned than the pruned plants. This result agrees with the findings of Myanmar (1999) and Zhang (1999).

Weight of Marketable Fruits Per Plant

The weight of marketable, unmarketable and the total weight of fruits per plant were significantly ($p<0.05$) affected by intra-row spacing in the first trial (Table 4). While in the second trial, intra-row spacing had no significant effect. In the first trial, 60 cm intra-row spacing (1.27 kg $plant^{-1}$) had higher marketable fruit weight per plant than 40 (1.03 kg $plant^{-1}$) and 20 cm (0.73 kg $plant^{-1}$) spacing while the unmarketable fruits were significantly higher in 20 and 40 cm intra-row spacing than 60 cm. Similar trend was observed for total weight of fruits per plant where significantly higher fruit weight per plant

Table 4: Weight of marketable, unmarketable and total fruits per plant as affected by intra-row spacing and pruning in 2004/05 and 2005/06 cropping seasons

	Weight of fruits per plant (kg)					
	2004/05			2005/06		
Treatments	MKT	UMKT	Total	MKT	UMKT	Total
Intra-row spacing (cm)						
20	0.73[c]	0.37[a]	1.02[c]	0.89	0.40	1.34
40	1.03[b]	0.37[a]	1.39[b]	0.97	0.37	1.24
60	1.27[a]	0.29[b]	1.64[a]	0.98	0.35	1.38
SE	0.02	0.01	0.02	0.05	0.03	0.06
Sig.	S	S	S	Ns	Ns	Ns
Pruning						
Three-stem	1.08[a]	0.36	1.44[a]	1.03[a]	0.39	1.36
Two-stem	0.99[b]	0.32	1.29[b]	0.96[b]	0.36	1.25
Unpruned	0.97[b]	0.34	1.33[b]	0.85[b]	0.38	1.35
SE	0.02	0.01	0.02	0.05	0.03	0.06
Sig.	S	Ns	S	S	Ns	Ns
Interactions						
Spacing×Prun.	S	S	S	Ns	Ns	Ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD. Ns = Not significant; s = significant at 5% level of significance, MKT = Marketable fruit, UMKT = Unmarketable fruits

was recorded with 60 cm intra-row spacing than 40 and 20 cm. Higher fruit weight in 60 cm intra-row spacing could be due to less competition for light, nutrients, water and space in 60 cm spacing than 20 and 40 cm intra-row spacing. Similar results were obtained by Rafi (1996), Myanmar (1999) and Rawshan (1996) where wider spacing increased marketable fruit weight per plant and reduced unmarketable weight per plant.

Pruning on the other hand, had significant ($p<0.05$) effect on marketable fruit weight per plant in both trials and total fruit weight per plant in trial 1 (Table 4).

Pruning did not affect unmarketable fruit weight per plant but had significant effect on total fruit weight per plant in the first trial. Significantly ($p<0.05$) higher fruit weight per plant was recorded in three-stem (1.08 and 1.03 kg plant^{-1} in trial 1 and 2, respectively) pruned plants than two-stem (0.99 and 0.96 kg plant^{-1} in trial 1 and 2, respectively) and unpruned (0.97 and 0.85 kg plant^{-1} in trial 1 and 2, respectively) plants in both trial 1 and 2. This could be due to greater proportion of the photosynthate being diverted to the three branches only in comparison with unpruned plants where the photosynthate is diverted to several branches whether productive or not. Pruning to two-stem might have resulted in excessive removal of branches thus affecting the photosynthetic capacity. Similar results were obtained by Chen and Lal (1999).

Mean Fruit Weight

Intra-row spacing had significant ($p<0.05$) effect on mean fruit weight in both trials separate and combined (Table 5). An intra-row spacing of 60 and 40 cm produced relatively similar mean fruit weight that was significantly higher than that of 20 cm spacing in both trials separate and combined. Rawshan (1996) and Ahmad and Singh (2005) reported similar response to intra-row spacing. This result could still be attributed to the minimal plant to plant competition exhibited by wider spacing (Kochlar and Joseph, 1986; Wesserman, 1985).

Pruning showed a significant ($p<0.05$) effect on mean fruit weight of tomato in both trials separate and combined (Table 5). Significantly higher mean fruit weight was recorded in three-stem and two-stem plants compared to unpruned plants. Furthermore, in combined analysis, two-stem plants produced the highest (52.19 g) fruit weight, followed by three-stem (48.83 g) and unpruned (38.86 g) plants. The reasons for the higher mean fruit weight in pruned plants than unpruned could be because the former had less photosynthate-demanding shoots which resulted to more dry matter partitioning to its fruits. Rafi (1996), Zhang (1999) and Myanmar (1999) independently reported similar findings. The effect of interaction between intra-row spacing and pruning on mean fruit weight (Fig. 1) showed that at all intra-row spacing, mean fruit weight in pruned plants was significantly higher than unpruned plants. The highest (61.92 g) mean fruit weight was obtained in two-stem pruned plants that were spaced at 60 cm. And least (32.5 g) was recorded in unpruned plants at 20 cm intra-row spacing. This better performance of the pruned treatments at all levels spacing could be due to distribution of the photosynthate to two or three branches only in contrast to unpruned plants where the photosynthate

Table 5: Mean fruit weight and total fresh fruit yield as influenced by intra-row spacing and pruning in 2004/05 and 2005/06 cropping seasons and the two years combined

	Mean fruit weight (g)			Total fresh fruit yield (t ha^{-1})		
Treatments	2004/05	2005/06	Combined	2004/05	2005/06	Combined
Intra-row spacing (cm)						
20	43.78^{b}	41.67^{b}	38.22^{c}	58.94^{a}	56.15^{a}	61.04^{a}
40	50.23^{a}	46.17^{a}	47.67^{b}	55.32^{a}	54.40^{a}	54.86^{b}
60	51.17^{a}	46.78^{a}	54.00^{a}	45.95^{b}	45.87^{b}	42.41^{c}
SE	0.32	1.06	0.52	1.44	1.09	0.85
Sig.	S	S	S	S	S	S
Prunning						
Three-stem	52.00^{a}	46.67^{a}	48.83^{b}	56.62^{a}	55.89^{a}	54.56^{a}
Two-stem	42.28^{b}	48.11^{a}	52.19^{a}	50.99^{b}	51.54^{b}	52.02^{ab}
Unpruned	40.89^{b}	39.83^{b}	38.86^{c}	52.60^{ab}	50.88^{b}	51.74^{b}
SE	0.32	1.06	0.52	1.44	1.09	0.85
Sig.	S	S	S	S	S	S
Interaction						
Spacing×Prun.	S	Ns	S	S	S	Ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD. Ns = Not significant; s = significant at 5% level

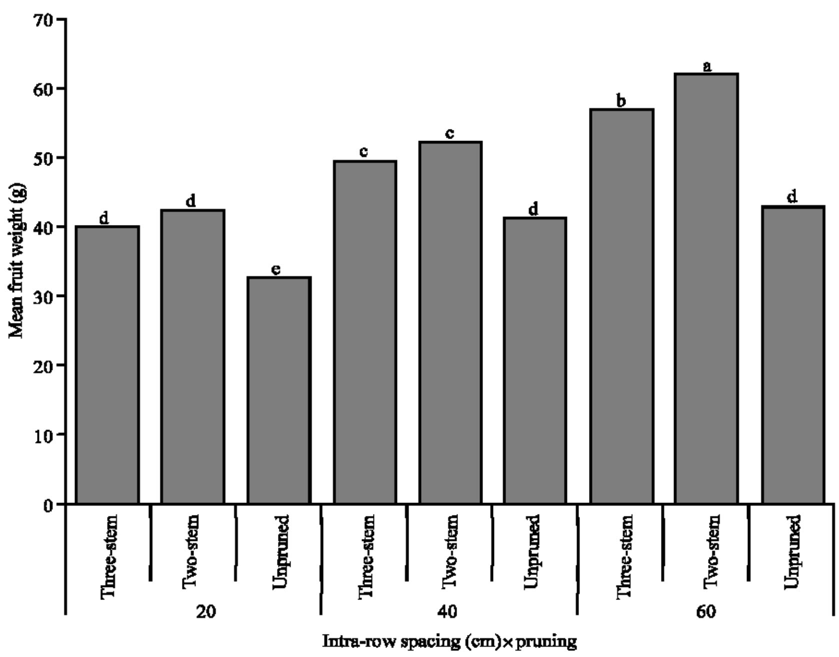

Fig. 1: Mean fruit weight of tomato as influenced by spacing×pruning interaction in the two years combined Bars with same letter(s) are not significantly different using DMRT at 5% level

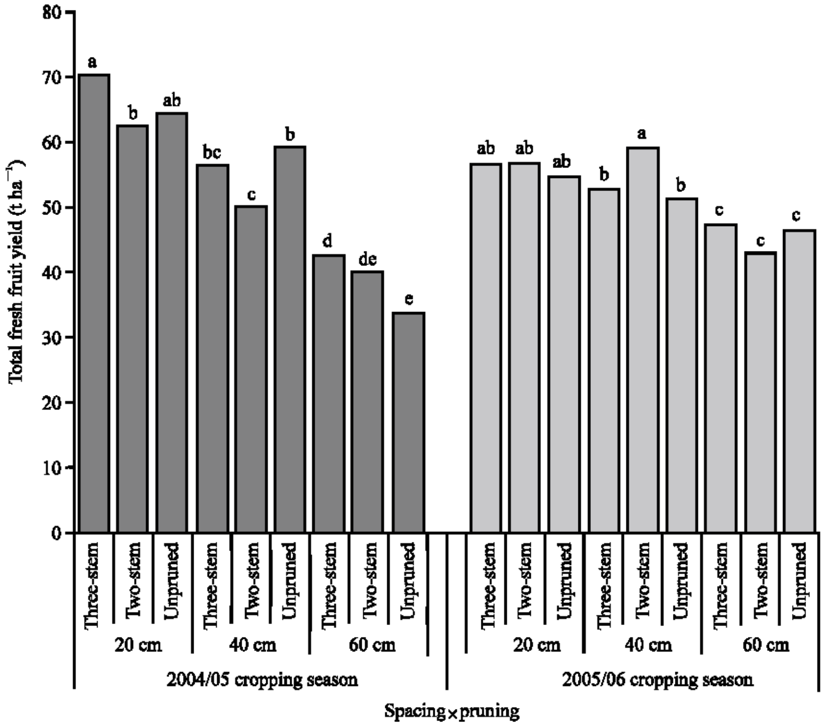

Fig. 2: Total fresh fruit yield of tomato as influenced by spacing×pruning interaction in 2004/05 and 2005/06 seasons using DMRT at 5% level

is partitioned to all the branches. In addition, pruning results in greater circulation of air and interception of light (less mutual shading) resulting into plants that are more productive and disease free (Dobson *et al*., 2002).

Total Fresh Fruit Yield

Intra-row spacing had significant ($p<0.05$) effect on total fresh fruit yield in both trials and the two trials combined (Table 5). Intra-row spacing of 20 and 40 cm recorded similar fresh fruit yield but significantly higher than 60 cm in the two trials separately and combined. This was because at closer intra-row spacings, higher plant density is obtained and this is a predetermining factor for unit area return as highlighted by Frabbel (1979) and Arnold (1986). Similar researches by Rafi (1996), Myanmar (1999) and Zhang (1999) revealed the same result and unanimously attributed it to the high number of fruits per plot due to higher population density in closely spaced treatment.

Pruning had significant ($p<0.05$) effect on the total fresh fruit yield of tomato in the two trials separate and combined (Table 5). In both trials, three-stem pruned plants recorded significantly higher fresh fruit yield than two-stem and unpruned plants. Similarly, in the two trials combined analysis, significantly higher fresh fruit yield was recorded in three and two stem pruned plants than unpruned plants. This result partially agrees with the findings of Rafi (1996) and Myanmar (1999) who worked on indeterminate tomato varieties. They both reported the same total fruit yield for three-stem and two-stem, which was significantly higher than unprunned. However, Zhang (1999) worked with determinate variety and reported highest total fruit yield in unpruned plants.

Effect of interaction between spacing and pruning on total fresh fruit yield (Fig. 2) was significant both in trial 1 and 2 and showed that, both two-stem and three-stem pruned plants had higher fresh fruit yield at 20 and 40 cm intra-row spacing. In both trials, highest yield (70.41 t ha^{-1}) was obtained in plants that were pruned to three-stem and spaced at 20 cm within the rows. The least yield was recorded (42.92 t ha^{-1}) in unpruned plants spaced at 60 cm intra-row spacing..

CONCLUSIONS

From the findings of this study it could be concluded that pruning of tomato could be practiced to increase the yield and quality of tomato. An intra-row spacing of 20-40 cm was appropriate for maximum fresh tomato yield and quality. Three-stem pruning coupled with closer intra-row spacing (20-40 cm) may be recommended for higher production of tomato variety (Roma VFN) in the Sudan savanna of Nigeria.

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