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Effects of Inter-Row Spacing and Weed Interference on Growth and Yield of Sorrel (*Hibiscus sabdariffa* L.) in Maiduguri, Nigeria

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***Abstract* – An experiment was conducted in 2009 and 2010 rainy seasons at the Teaching and Research farm of the Department of Crop Production, University of Maiduguri (Sudano-Sahelian zone) of Borno State (11⁰ 50′ N and 13⁰ 10′E) to determine the effects of spacing and weed interference on the growth and yield of sorrel (*Hibiscus sabdariffa* L.). The treatments consisted of inter-row spacing at 30, 60, and 90 cm apart and weed interferences of weed free period for 3, 6, 9 weeks after sowing (WAS) and weed free till harvest, and weed infested period for 3, 6, 9 WAS and weed infested till harvest. These treatments were laid out in a split plot design replicated 3 times. The spacing treatments were laid out in the main-plots while the weed interferences were laid out in the sub-plots. Seeds were dibbled at a constant intra-row spacing of 60 cm. Parameters measured included stand count/net plot, number of branches per plant, number of calyx per plant, fresh and dry calyx yield, seed yield and weed dry matter. Data from the experiment was subjected to Analysis of variance (ANOVA). The results show that there were significant differences among the treatment means of spacing where the stand count at 30 cm x 60 cm spacing produced the highest number of plants and yield. 90 cm x60 cm produced the highest number of calyx per plant. Significant weed interference was obtained at weed infested for 3 WAS giving higher calyx yield and seed yield in order of, 84% and 95% compared with weed free till harvest. Weed dry matter was highest (358.85 kg/ha weed weight) in the weed infested treatment till harvest compared with the weed free treatment. The significant interaction between spacing and weed interference was at 90 cm x 60 cm and weed free for 9 WAS which resulted in the highest number of branches and highest number of calyx . In conclusion, Sorrel is best grown for its calyx and seed yield at closest spacing of 30 cm x 60 cm. furthermore, sorrel need to be kept weed free from 3-9 WAS for higher yield.**

***Keywords* – Sorrel, Weeding, Spacing, Calyx, Yield.**

I. INTRODUCTION

Sorrel *(Hibiscus sabdariffa* L.) is an important vegetable crop in northern and southern Nigeria (Alegbejo, 2000). The crop is recognized in the World at large for its value (vegetable, medicinal, beverage e t c) and its increasing demand (Steve, 2003) and therefore warrants an urgent need for research in the aspect of yield increase.

The tender leaves of the plant are used for making soup in the northern and southern states of Nigeria. More popularly the calyx of the red type is used nowadays as a beverage drink, it is partially boiled in hot water, strained and sugar is added to taste. The liquid is chilled and taken as a soft drink commonly called "zobo" drink. The calyx is also made into jellies, sauces, chatneys and preservers. The tender leaves and stalks are eaten as salad and as pot herb and are used for seasoning curry (Alegbejo, 2000). The seed contains oil, and contains 4% citric acid. Traditionally, preparation from various part of the plant such as flowers, leaves, calyx and corolla are used as remedy for various illness (Onyenekwe, 1998). Roselle leaves are emollient and used as diuretic, sedative and refrigerant while the fruits are considered antisorbutic. Calyx infusion is considered diuretic, choleretic, intestinal antiseptic and mild laxative, refreshing and considered useful in bilious conditions, heart and nerve diseases, high blood pressure and calcified arteries. It is used to reduce/ameliorate hypertension (Onyenekwe, 1998). The soft fibres of the stem are used for coarse fabrics such as canvas and sacks (Dempsey, 1975).

Effects of spacing on growth of vegetables: Katung *et al.* (2000) reported that for most crops weed competition during the first quarter of the growth period was observed to be very critical because the damage to the crop at this stage is irreparable. In order to boost the production of sorrel, adequate research needs to be conducted. The inter-and intra-row spacing for optimum yield should be determined (Alegbejo, 2000). Kabura *et al.* (2003) reported that for the production of calyx of sorrel in the Sudan Sahelian region plant of spacing of 60 x 30 cm should be encouraged. Inter row spacing did not have any significant effect on growth and yield of tomato except in Kadawa in 1987/88 dry season where 30 and 40 cm spacing resulted in similar tomato fruit yields which were significantly higher than that of 60 cm spacing. Spacing of 30 cm also resulted in higher number of leaves than 60 cm spacing (Adigun *et al.*, 1994). However maximum number of calyx and maximum dry weight of calyx per stand were generally greatest at widest spacing. Smith and Ojo (2007) carried out an experiment to determine the influence of intra row spacing and weed management system on gap colonization of weeds, pod yield and quality in okra (*Abelmoschus esculentus* (L.) Moench) in 2004 and 2005 in Southwestern Nigeria indicated that narrow intrarow spacing 30 cm is recommended for optimum okra pod yield. Tenaw *et al.* (2011) in their report on effects of plant density, variety and weeding frequency on net economic benefit of sweet potato stated that high yield was attributed to increased plant density.

Effect of Weed Association on Vegetable Crops: Most weed species usually occur in association with other plants, either crop or weeds. It is important to consider the

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manner in which weeds interact with neighbours in the agricultural ecosystem because they interact in a number of ways and to varying degrees (Pereira, 2008).Karaye and Yakubu (2005) reported that the response weed growth and bulb yield of garlic results indicated that the number of leaves per plant, weed growth and cured bulb yield responded significantly to intra row spacing and mulching and concluded that intra row spacing of 10 cm should be adopted. El-naim *et al*. (2012) in their study on sorrel reported that weeding three times at 15, 30 and 45 days after sowing are effective to control weeds and recommended to improve yield of sorrel crop in sandy dunes. Piyatida and Hisashi (2011) on their evaluation of allelopathic activity of *Hibiscus sabdariffa* reported *H. sabdariffa* may posses allelopathic potential and may contain growth inhibitory substances and hence may be used as environmentally friendly herbicide to control weeds. Gworgwor (1990) reported that weed association with irrigated tomato during the cool dry season at Maiduguri in the semi arid zone of Nigeria shows that weed infestation for 6 WAT and later significantly depressed crop vigour as compared with the crop kept weed free for the corresponding periods. The critical period of weed competition was observed to be 6 WAT the uncontrolled weed association till harvest resulted in 51.7% and 63% losses in 1987 and 1988 respectively in tomato fruit yield. Adjun (2003) also observed that weeding three times resulted in high crop vigour score and yield. Results of weed association and spacing on soyabean in Sudan savanna region of Nigeria indicated that plant height, number of pods per plant and grain yield, increase with increase in number of weedings, whereas weed dry biomass decreased with increase in number of weedings (Sodangi *et al.,* 2006). El-Naim and Ahmed (2010) reported that weeding three times at 2, 4 and 6 weeks after sowing (WAS) was optimal for plant height, leaf area index, number of branches, number of calyx per plant, calyx diameter and calyx yield per unit area in their study to determine the effect of weed interference on growth and yield of two Roselle (*Hibiscus sabdariffa* L.) varieties under rainfed condition in North Kordofan of Sudan. Kuchinda *et al*. (1991) observed fibre yield and capsule reductions of 47.2% and 30.0% due to unrestricted weed growth in kenaf.

Therefore the objectives of the study were to determine the most appropriate spacing and critical period of weed interference on the growth and yield of sorrel.

II. Materials and Methods

Experimental Site

The experiment was conducted at the Department of Crop Production Teaching and Research farm, Faculty of Agriculture University of Maiduguri, Maiduguri (11°50'N: 13°10'E and 319 m asl) during the rainy seasons of 2009 and 2010 between June and September. The physiochemical characteristics of the experimental site are: pH in water 6.43 slightly acidic, organic carbon 5.30 g/kg, organic matter 7.04 g/kg, available phosphorus 4.55 g/kg, available potassium 3.10 g/kg. Field texture is sandy loam with clay15.60%, sand 70.30%and silt 14.10%

The research area is commonly characterized by growing sorrel as a border plant; either to protect their main crops or to mark border between two different farms. The crops grown previous year in the experimental area include pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata* L. Walp), groundnut (*Arachis hypogaea*). Some major weeds that associate with crops in that area include *Ipomoea* spp, *Merremia aegyptia*, *Cenchrus biflorus* Roxb, and *Commelina benghalensis* are found among others. The most common methods of weed control are mainly hand weeding and use of herbicides.

Treatments and Experimental Design

The treatments consisted of 2 factors which are inter-row spacing and weed interferences which were laid out in a split-plot design. The inter row-spacing was in the main plot, and consisted of 3 inter-row spacings of 30 cm, 60 cm and 90 cm and intra-row spacing of 60 cm was maintained for all treatments. The weed interference was assigned to the sub-plot. These comprised 8 weed interference treatments; weed infested for 3, 6, and 9 weeks, and weed infested till harvest, and weed free for 3, 6, and 9 weeks and weed free till harvest. These treatments were replicated three times. The gross plot size was 3 m x 4 m (12 m^2) and sampling was done from the net plot of 2 m x 3 m (6 m^2).

Cultural Practices

The farm was neatly cleared of debris, harrowed by tractor and leveled manually with hand hoe. Plots were laid out according to the design, using measuring tape, pegs and rope to equally get the plots on 3 straight rows. Five seeds/hole were sowed initially and later plants were thinned to 3 plants per stand at 3 WAS. Weeding was done according to the treatments manually using the African hand hoe. Urea at 92 kg N/ha was applied by side dressing at 4 WAS, and at flowering time by equal split application (Kabura *et al.,* 2003). At maturity calyx yield was harvested by hand, separating the calyx from the seed capsule after which they were allowed to sun dry.

Parameters measured

stand count per net plot, plant height (cm), number of calyx per p1ant, fresh and dry calyx yield per net plot (g), number of branches per plant, seed yield per net plot (g), and weed dry matter per net plot (g) and correlation analysis. All weight parameters were based on (g) per net plot but later converted to kg/ha for the sake of analysis.

Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) using Statistix 8.0® software (Analytical Software, 2008). Simple correlation analysis was carried out on growth and yield of sorrel. The difference between means was separated by Duncan's Multiple Range Test at 5% level of probability.

III. Results

Stand Count of Sorrel per Net Plot at Harvest

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The spacing of sorrel significantly influenced the number of plant stands in both years and the combined mean (Table 1). The closer spacing at 30cm had the highest plant stands than the 60 and 90 cm spacings as well as the 60 cm spacing having significantly higher stand count than the 90 cm spacing (Table 1). There was however, no significant effect of the weed interference and the effect of interaction between spacing and weed interference on the stand count of sorrel in both years and the combined mean at 2 WAS (Table 1).

At harvest, there was a significant effect of spacing, weed interference and the interaction between spacing and weed interference on the stand count of sorrel per plot (Table 1). In both years and the combined mean, the closer spacing of 30 cm had significant higher number of stand of sorrel compared with the 60 and 90 cm spacing. Similarly, the 60cm spacing had significantly highest stand count than the 90 cm spacing (Table 1).

Table 1: Effects of spacing and weed interference on the stand count of sorrel at 2 WAS and at harvest in 2009 and 2010 rainy seasons and combined mean at Maiduguri

Treatment	Stand count/net plot at 2 WAS			Stand count/net plot at harvest		
	2009	2010	Mean	2009	2010	Mean
Spacing (cm) (S)						
30	15.46[a1]	14.92[a]	15.19[a]	11.33[a]	10.67[a]	11.00[a]
60	7.75[b]	8.00[b]	7.88[b]	5.83[b]	5.29[b]	5.56[b]
90	4.00 4.00[c]	4.00[c]	4.00[c]	3.08 3.08[c]	2.92[c]	3.00[c]
SE(±)	0.14	0.57	0.22	0.23	0.48	0.24
Weed interference (WI)						
Weed infested for 3 weeks	9.22	8.67	8.94	9.11[ab]	7.89[a]	8.50[a]
Weed infested for 6 weeks	9.22	8.78	9.00	8.56[ab]	8.89[a]	8.72[a]
Weed infested for 9 weeks	9.11	9.00	9.06	7.00[c]	5.22[b]	6.11[b]
Weed infested till harvest	9.11	9.33	9.22	1.22[d]	0.78[c]	1.00[c]
Weed free for 3 weeks	9.11	9.37	9.22	1.89[d]	0.78[c]	1.33[c]
Weed free for 6 weeks	9.11	8.67	8.89	8.33[b]	8.67[a]	8.50[a]
Weed free for 9 weeks	8.89	8.78	8.33	8.67[ab]	9.11[a]	8.89[a]
Weed free till harvest	8.78	9.22	9.00	9.22[a]	9.00[a]	9.11[a]
SE(±)	0.39	0.44	0.31	0.44	0.63	0.42
Interaction (S x WI)	NS[2]	NS	NS	*[3]	*	*

[1] Means in the same column followed by the same letter(s) are statistically the same at 5% level of probability (DMRT)
[2] Not significant
[3] Significant at 5% level of probability

Effect of Spacing and Weed interference on the Number of branches and Calyx per Sorrel Plant

The effects of inter-row spacing and weed interference on the number of branches per plant was significant at harvest in both years and the combined mean (Table 2). Similarly, the effect of interaction between spacing and weed interference was significant in 2009 and highly significant in 2010 and the combined mean on number of branches per plant. The widest spacing of 90 cm gave significantly the highest number of branches per plant than the closer spacings of 30 cm in 2009, 2010 and combined mean and 60 cm in 2010 (Table 2). weed free for 9 weeks and weed free till harvest produced significantly the highest number of branches compared with the rest of the weed interference treatments though at par with weed infested for 6 WAS in 2010 and weed free for 6 WAS in the combined mean (Table 2). The effect of interaction between spacing and weed interference on number of branches per plant was significant.

Table 2: Effects of spacing and weed interference on number of calyx per sorrel plant in 2009 and 2010 rainy seasons and combined mean at Maiduguri

Treatment	Number of branches per plant			Number of calyx per plant		
	2009	2010	Mean	2009	2010	Mean
Spacing (cm) (S)						
30	5.42[b1]	4.00[b]	4.71[c]	9.21[b]	12.50[b]	10.58[c]
60	6.83[b]	5.38[ab]	6.10[b]	12.79[b]	9.54[b]	11.17[b]
90	8.58[a]	7.00[a]	7.79[a]	21.54[a]	19.46[a]	20.50[a]
SE(±)	0.57	0.62	0.29	1.94	1.87	0.09
Weed interference (WI)						
Weed infested for 3 weeks	9.56[a]	7.76[a]	8.61[a]	15.89[c]	21.22[ab]	18.56[ab]
Weed infested for 6 weeks	6.56[cd]	6.56[a]	6.55[bc]	19.00[a-c]	15.11[cd]	17.06[b]
Weed infested for 9 weeks	6.89[c]	4.22[b]	5.56[c]	10.78[d]	11.33[d]	11.06[c]

Weed infested till harvest	5.00^{d}	0.67^{c}	2.83^{d}	6.44^{e}	2.00^{e}	4.22^{d}
Weed free for 3 weeks	3.11^{e}	2.00^{c}	2.56^{d}	5.67^{e}	3.67^{e}	4.67^{d}
Weed free for 6 weeks	7.56^{bc}	7.44^{a}	7.50^{ab}	17.22^{bc}	15.44^{cd}	16.33^{b}
Weed free for 9 weeks	8.11^{a-c}	7.78^{a}	7.50^{ab}	21.11^{a}	18.22^{bc}	19.67^{ab}
Weed free till harvest	8.78^{ab}	7.33^{a}	8.06^{a}	20.00^{ab}	23.67^{a}	21.83^{a}
SE(±)	0.89	0.82	0.72	1.84	2.11	1.70
Interaction (S x WI)	*[2]	***[3]	***	**[4]	***	***

[1] Means in the same column followed by the same letter(s) are statistically the same at 5% level of probability (DMRT)
[2] Significant at 5% level of probability. [3]Significant at 0.1% level of probability. [4]Significant at 1% level of probability

The number of calyx per plant was significantly affected by the spacing treatments in both years and the combined mean (Table 2). The wider the spacing at 90 cm the higher the number of calyx per plant compared with the closer 30 cm and 60 cm (Table 2) Similarly, the weed interference treatments had significant effect on the number of calyx per plant in both years and the combined mean (Table 2). In both years and the combined mean keeping the crop weed free till harvest produced the highest calyx per plant, but comparable with weed free for 9 WAS in 2009 and the combined mean and weed infested for 3 WAS in 2010 and the combined mean (Table 2).

The effect of interaction between spacing and weed interference treatments was highly significant on the amount of calyx produced per plant in both years and the combined mean (Table 2).

Effects of Spacing and Weed interference on Fresh and Dry Calyx Yield (kg/ha) of Sorrel

The effects of spacing, weed interference and the interaction between spacing and weed interference on fresh calyx weight of sorrel were significant in both years and the combined mean (Table 3). In both years and the combined mean significantly higher calyx yields were obtained at the closer 30 cm spacing compared with the 60 and 90 cm spacings (Table 3). There was significantly higher yield in 2009, 2010 and the combined mean when sorrel was kept weed free for 9 weeks and longer, and weed free for 6 WAS in the combined mean compared to when sorrel was allowed to grow with weeds till harvest or earlier and was free from weeds for 3 and 6 weeks in 2009 and 2010 (Table 3).

The effect of interaction between spacing and weed interference in 2009 on fresh calyx yield of sorrel was significant in both years and the combined mean (Table 3). Dry calyx weight of sorrel at harvest was significantly affected by spacing in 2009, 2010 and the mean analysis (Table 3). At the close spacing of 30 cm, significant highest dry calyx weight was obtained compared to the wide spacings of 60 and 90 cm, except in 2010 where 60 cm spacing had significantly highest dry calyx yield than 90 cm. (Table 3).

Similarly, dry calyx weight of sorrel at harvest was significantly affected by weed interference in both years and the combined mean (Table 3). Plants kept weed free till harvest had the highest dry calyx weight statistically the same with weed free for 9 weeks and weed infested for 3 WAS in 2010 compared with the rest of the weed interference treatments except for weed infested for 3 weeks (Table 3).The effect of interaction between spacing and weed interference on dry calyx yield of sorrel in 2009 had significant difference while in 2010 and the combined analysis showed no significant difference (Table 3)

Table 3: Effects of spacing and weed interference on fresh and dry calyx yield in 2009 and 2010 rainy season and combined mean at Maiduguri

Treatment	Fresh calyx Yield at harvest(kg/ha)			Dry calyx Yield at harvest (kg/ha)		
	2009	2010	Mean	2009	2010	Mean
Spacing (cm) (S)						
30	1434.0^{a1}	1581.0^{a}	1507.5^{a}	526.83^{a}	283.47^{a}	405.15^{a}
60	905.5^{b}	870.2^{b}	887.9^{b}	303.97^{b}	208.89^{a}	256.43^{b}
90	841.7^{b}	667.6^{b}	754.7^{c}	232.95^{b}	121.31^{b}	177.13^{c}
SE(±)	4 1.93	74.90	43.09	40.24	30.77	27.96
Weed interference (WI)						
Weed infested for 3 weeks	1815.7^{b}	1593.7^{b}	1704.7^{b}	670.00^{b}	345.22^{ab}	532.11^{b}
Weed infested for 6 weeks	1041.8^{c}	874.1^{c}	957.9^{c}	294.67^{c}	163.15^{cd}	228.91^{c}
Weed infested for 9 weeks	301.1^{d}	349.1^{d}	325.1^{d}	54.09^{d}	62.54^{de}	58.32^{d}
Weed infested till harvest	37.0^{e}	12.4^{e}	24.7^{e}	3.67^{d}	0.07^{e}	1.87^{d}
Weed free for 3 weeks	80.6^{de}	15.9^{e}	48.2^{e}	24.55^{d}	4.50^{e}	23.14^{d}
Weed free for 6 weeks	816.7^{c}	1459.6^{b}	2036.7^{a}	210.65^{c}	267.22^{bc}	238.93^{c}
Weed free for 9 weeks	2088.7^{a}	1984.6^{a}	2036.7^{a}	770.00^{ab}	346.11^{ab}	558.06^{ab}
Weed free till harvest	2301.7^{a}	2027.4^{a}	2164.6^{a}	869.00^{a}	459.63^{a}	664.31^{a}
SE(±)	123.48	109.88	103.30	76.44	71.25	70.58
Interaction (S x WI)	***[2]	***	***	***	NS[3]	NS

[1] Means in the same column followed by the same letter(s) are statistically the same at 5% level of probability (DMRT)
[2] Significant at 0.1% level of probability [3]Not Significant

Effect of Spacing and Weed interference on Seed Yield (kg/ha) and 1000 Seed Weight of Sorrel.

Seed yield of sorrel was significantly affected by spacing, the weed interference treatments and the interaction between spacing and weed interference in both years and the combined mean (Table 4). In both years and the combined mean, 30 cm and 90 cm spacings significantly produced the highest seed yield compared with the spacing of 60 (Table 4). Similarly, in both years and the combined mean, plots kept weed free for 9 weeks and weed free till harvest and plots infested for the 3 weeks in 2009 and the combined mean produced the highest seed yield compared with plots kept weed free for 3 weeks and those infested for 9 WAS and beyond (Table 4).

Table 4: Effect of spacing and weed interference on seed yield (kg/ha) of sorrel in 2009 and 2010 rainy seasons and combined mean at Maiduguri.

Treatment	Seed yield at harvest (kg/ha)		
	2009	2010	Mean
Spacing (cm) (S)			
30	130.03[a]	132.25[a]	131.14[a]
60	70.37[b]	77.71[b]	74.04[b]
90	95.23[ab]	61.79[c]	78.51[b]
SE(±)	13.76	3.89	5.50
Weed interference (WI)			
Weed infested for 3 weeks	176.96[a]	141.94[b]	159.45[a] (10%) [2]
Weed infested for 6 weeks	92.42[bc]	80.39[d]	86.41[b] (51%)
Weed infested for 9 weeks	53.52[c]	36.16[e]	44.84[c] (75%)
Weed infested till harvest	4.24[d]	0.75[f]	2.49[d] (99%)
Weed free for 3 weeks	12.57[d]	1.72[f]	7.15[d] (96%)
Weed free for 6 weeks	103.86[b]	113.72[c]	108.79[b] (39%)
Weed free for 9 weeks	174.26[a]	164.44[ab]	169.35[a] (0.5%)
Weed free till harvest	170.54[a]	185.52[a]	178.03[a]
SE(+)	19.42	11.34	12.45
Interaction (S x WI)	***[3]	***	***

[1] Means in the same column followed by the same letter(s) are statistically the same at 5% level of probability (DMRT)
[2] Numbers in parenthesis are percentage seed yield loss against the weed free till harvest.
[3] Significant at 0.1% level of probability
[4]Not significant

Table 5: Effect of spacing and weed interference on weed dry matter (kg/ha) in sorrel at 8 WAS in 2009 and 2010 rainy seasons and combined mean at Maiduguri.

Treatment	Weed dry matter (kg/ha) 8 WAS		
	2009	2010	Mean
Spacing (cm) (S)			
30	93.93[b1]	89.10[c]	91.51[c]
60	117.91[ab]	141.71[b]	129.81[b]
90	126.55[a]	189.66[a]	158.10[a]
SE±	11.29	16.61	5.99
Weed interference (WI)			
Weed infested for 3 weeks	13.08[d]	15.72[c]	14.40[d] (4%)[2]
Weed infested for 6 weeks	12.92[d]	50.25[c]	31.59[d] (9%)
Weed infested for 9 weeks	285.65[b]	379.13[a]	332.39[b] (99%)
Weed infested till harvest	329.96[a]	387.73[a]	358.85[a]
Weed free for 3 weeks	220.37[c]	244.45[b]	232.41[c] (65%)
Weed free for 6 weeks	30.04[d]	30.46[c]	30.25[d] (8%)
Weed free for 9 weeks	12.17[d]	15.55[c]	13.86[d] (4%)
Weed free till harvest	13.17[d]	12.98[c]	13.08[d] (4%)
SE(+)	14.76	28.53	18.45
Interaction (S x WI)	***[3]	***	***

[1] Means in the same row and column followed by the same letter(s) are statistically the same at 5% level of probability (DMRT)
[2] Numbers in parenthesis are percentage weed dry matter against the weed infested till harvest.
[3]Significant at 0.1% level of probability.

Effect of Spacing and Weed Interference on Weed Dry Matter in Sorrel

Weed dry matter was significantly affected by spacing treatment and weed interference and the interaction between spacing and weed interference in both years and combined mean were also (Table 5). In both years and the combined mean, the 90 cm widest spacing produced the highest weed dry weight at 8 weeks compared with the 30 cm and 60 cm in 2009, although it was at par with the 60 cm spacing.

In both years and the combined mean analysis, plots kept weed infested for 3 and 6 weeks and weed free for 3 weeks and beyond and weed infested till harvest produced significantly the lowest weed dry weight compared with weed infested for 9 weeks and till harvest (Table 5). Keeping the plots weed infested for 3, 6 and 9 weeks resulted in dry weed weight of 4%, 9% and 99% respectively compared with keeping the sorrel plots weed free for 3, 6 and 9 weeks could result in dry weed weight of 65%, 8% and 4% respectively (Table 5).

The interaction between spacing and weed interference on weed dry matter was significant in both years and the combined mean (Table 5).

4.12.1 Linear Correlation among growth and yield parameters in sorrel in 2009

Stand count of sorrel at harvest had highly significant positive correlation with the number of leaves per plant at harvest, plant height at harvest, the number of seed/capsule, fresh and dry calyx weight and seed yield, and highly significant negative correlation with weed cover score at 6 and 9 WAS, and weed dry matter (Table 6). Plant height at harvest had highly significant negative correlation with weed cover score at 6 and 9 WAS but highly significant positive correlation with all other parameters (number of calyx per plant, number of seed per capsule, number of branches per plant, fresh and dry calyx, fresh and dry leaf weight and seed yield). Weed cover score at 6 and 9 WAS had highly significant negative correlation with the number of calyx per plant, the number of branches per plant, fresh and dry calyx weight and seed yield. Weed dry matter had highly negative correlation with fresh leaf yield but highly significant positive correlation with dry calyx weight and seed yield. Fresh calyx weight had highly significant positive correlation with fresh and dry leave yield, weed dry matter, dry calyx and seed yields (Table 6).

IV. Discussions

Effect of Spacing on the Growth and Yield of Sorrel

Although spacing treatment did not significantly affect stand count of sorrel at 2 WAS in the 2 years of the study, stand count at harvest was significantly affected by spacing treatment. The 30 cm spacing had significantly the highest number of stands per net plot than the wider spacings of 60 cm and 90 cm. This could be useful in suppressing weed growth and giving high rate of photosynthesis which leads to increase in yield. This finding tally with the work of Kabura *et al.* (2003) who reported that higher stand count at 30 x 60 cm spacing is optimum for yield of dry calyx in sorrel. Smith and Ojo (2007) also reported effectiveness of closer spacing in okro for giving higher population for effective weed suppression. However, Ibeawuchi *et al.* (2005) reported contrary findings that an increase in spacing of okro with groundnut had the highest yield than the closer spacing. Also for both fresh and dry calyx yield as well as seed yield, higher plant population at closer 30 cm spacing had the highest yield. Dry calyx yield decreased from 869.00 kg/ha to 3.67 kg/ha in 2009 (98% yield loss) and from 459.67 kg/ha to 0.07 kg/ha in 2010 (99% yield loss) due to weed competition (infestation till harvest). Inter row spacing did not have significant effect on number of seed /capsule in the 2 years study, as well as there was no significant difference in 1000 seed weight in 2010. This might be attributed to genetic and environmental factors and inter play of these factors as has been reported by Katung *et al*. (2000) on kenaf being in the same family with sorrel.

However, there was a marked yield difference between the 2 years, with higher yield in 2009 than 2010 and this might be due to higher rainfall recorded in 2009 at the peak of the crops' growth than that of 2010.

Effect of Weed interference on the Growth and Yield of Sorrel

Weed interference had no significant difference on stand count of sorrel at 2 WAS. The initial weed interference of the crop at 3 WAS had no significant effect. This is probably because major weed challenges occurred after 3 weeks of planting and also initial stage of crop growth, as the crops and weeds have adequate amount of sunlight, nutrients and water requirements. These finding agrees with the work of Adigun *et al.* (1994) on tomato.

Yield parameters such as fresh and dry calyx yield, fresh and dry leaf yield, seed yield and growth parameters such as plant height, number of leaves per plant, number of branches per plant, number of calyx per plant were significantly affected by weeding interference as there was significant increase in yield with the length of weed free period for 9 WAS and more. The yield of calyx in the weed free period for 9 WAS and beyond was comparable to that of weed infested for the first 3 weeks; because of no weed competition this report was contrary to the work of El-naim *et al*. (2012) who recommended weeding roselle at 15 DAS as the best.

Number of calyx and seed yield per plot increased significantly with increase in length of weed free period for up to 9 WAS but decreased significantly with increase in periods of weed interference. The seed yield reduction ranged from 4% in the weed free period to 94% in the weed infested period. This agrees with the work of Adjun. (2003) where he observed that weed free plants resulted in higher yield than weed infested ones. Similarly, unchecked weed growth caused significant yield reduction in tomato (Gworgwor, 1990). El-Naim and Ahmed (2010) also reported increase in yield as weeding period was increased from 6 WAS and above in tomatoes and sorrel.

Furthermore, when weeds were allowed to grow unchecked throughout the growing period the calyx yield of sorrel was by 99%. In the combined data analysis, when the crop was kept weed free up to the first 3, 6 and 9 WAS sorrel yield reduction were in the order of 96%, 64% and 16%, respectively. By keeping the plots weed infested up to 3, 6, and 9 WAS and till harvest the reduction in dry calyx yield was in the order of 19 %, 65%, 91% and 99% respectively. These results indicate that by allowing weeds to compete with the crop for the first 3 WAS followed by weed free up to harvest the loss was minimal. But when weeds were allowed to grow further up to 6 WAS and longer yield reductions were severe due to severe weed competition. Furthermore, the calyx yields from weed free period for 9 WAS and till harvest were similar. This was because regrowth of weed after 9 WAS could not compete with the crop so severely at that stage of crop growth. Similar calyx yield and seed yield were obtained in the case of weed free conditions from 9 WAS up till harvest. This finding agrees with the work of Adigun *et al*. (1994) who reported between 87% and 47.9% yield loss in sweet pepper and Kuchinda *et al*. (1991) observed fibre yield and capsule reductions of 47.2% and 30.0% due to unrestricted weed growth in kenaf all due to unrestricted weed growth.

Effect of Spacing and Weed interference on Weed Dry Matter in Sorrel

Weed dry matter obtained for the mean of 2 years study shows that closer spacing at 30 cm had the least weed dry weight (91.5 kg/ha) compared with the higher weed dry weight obtained (158.10 kg/ha) at the wider spacing of 90 cm. This is because closer plants grew tall and formed quick close canopy to suppress the growth of weeds contrary to wider spacing. This report agrees with the work of Smith and Ojo (2007) where they reported established okra plants have developed full canopy for sustained weed suppression in closer 15 cm spacing.

Initial weed infestation for only 3 WAS in sorrel did not significantly affect yield. This may be because major weed challenge occur mainly after 3 WAS. In addition initial stage of growth in both crops and weeds have adequate amount of light, nutrients and water to their requirements Periera (2008). Higher weed densities were obtained at periods when crops were weed infested for longer time. Furthermore, effect of weed interference on weed dry matter had significant effect at 8 WAS when sorrel plants were kept weed infested resulting in high weed dry weight of 329.96 kg/ha and 387.73 kg/ha in 2009 and 2010, respectively . This gave the highest weed dry weight than all other weed interference treatments. This may have been because unchecked long period of weed growth in plants drastically reduce yield. El-Naim and Ahmed (2010), Tenaw *et al*. (2011) and El-Naim *et al*. (2012) have reported similar findings.

Correlation Coefficient among Growth and Yield Parameters in sorrel

In both years similar correlations were observed between the growth and yield parameters of sorrel such as stand count at harvest, number of leaves per plant at harvest, plant height at harvest, fresh and dry leave weight, fresh and dry calyx yield and seed yield. The growth parameters had positive correlations with the yield parameters indicating that a good growth unaffected by weed infestation, equally resulted in higher dry matter and yield of sorrel. However there was no correlation between growth at early stage and weed parameters such as weed cover score and weed dry matter; this was probably because weeds have not grown much at the early stage of the crops' growth. But there was negative correlation between yield and weed parameters later which also indicated that weeds directly affected yield of sorrel in a negative way when left to grow unchecked and a positive effect when removed at the right time during the growth stage of the crop. This result agrees with Sodangi *et al*. (2006) where he reported similar findings.

Table 6: Correlation coefficient among growth and yield parameters of Sorrel in 2009 and 2010

	LVS4	SC2	SCH	LVSH	PH4	PHH	WC6	WC9	CLXPP	Seedcap	BRPP	Fclxwgha	DLW8kgha	Wdm kg/ha	Fly8kgha	Dclxwkgha
LV54	1.000															
SC2	0.080*	1.000														
SCH	0.176**	0.648***	1.000													
LVSH	0.006	-0.069	0.409***	1.000												
PH4	0.539***	0.032	0.117	0.047	1.000											
PHH	-0.021	-0.055	0.466***	0.738**	0.039	1.000										
WC6	-0.142	-.0.033	-0.329***	-0.385	-0.187**	-0.519***	1.000									
WC9	-0.174**	-0.003	-0.492***	-0.604***	-0.090	-0.736**	0.596***	1.000								
CLXPP	0.140	-0.381***	0.106	6.527***	0.188**	0.593***	-0.403***	-0655***	1.000							
Seeds cap	-0.007	-0.037	0.414***	0.536***	0.100	0.602***	-0.302***	0.487***	0.566***	1.000						
BRPP	0.221**	-0.318***	0.167*	0.464***	0.323***	0.577***	-0.049***	-0.610***	0.694***	0.642***	1.000					
Fclxwkgha	0.277***	0.283***	0.720***	0.528***	0.157	0.594***	-0.659***	-0.757***	0.447***	0.440***	0.421***	1.000				
DLW8kgha	-0.067	-0.140	0.194**	0.454***	0.065	0.580***	-0.696***	-0.576***	0.519***	0.386***	0.475***	0.550***	1.000			
WDMkgha	-0.235**	-0.133	-0.562***	-0.477***	-0.231**	0.652***	0.687***	0.663	0.573***	-0.496***	0.591***	0.722***	-0.553***	1.000		
FLY8kgha	-0.032	-0.161	0.220**	0.515***	0.090	0.577***	-0.751***	-0.610	0.562***	0.397***	0.508***	0.605***	0.926***	-0.576***	1.000	
DCLxwkgha	0.382***	0.263***	0.597***	0.401***	0.202**	0.432***	-0.536***	-.0616	0.301***	0.272***	0.349***	0.841***	-0.394***	0.569***	0.456***	1.000
Sdy/kga	0.267**	0.204**	0.629***	0.519***	0.162*	0.553***	-0.632***	-0.707	0.519***	0.405***	0.451***	0.853***	-0.527***	0.696***	0.591***	0.706***

*: significant at 5% level of probability **: significant at 1% level of probability ***: significant at 0.1% level of probability

Key

Lvs4- Number of leaves/plant at 4 weeks

SC2 - Stand count at 2 WAS

Seedcap - Number of seeds/capsule

Brpp - Number of branches/plant

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SCH - Stand count at harvest
LVSH - Number of leaves plant at harvest
PH4 - Plant height at 4 WAS
WC6 - Weed cover at 6 WAS
WC9 -Weed cover at 9 WAS
CLXPP - Number of calyx/plant
Fclwkgha -Fresh calyx weight kg/ha
Dlw8kgha - Dry leave yield at 8 WAS kg/ha
Wdm -Weed dry matter kg/ha
Fly8kgha - Fresh leaf yield kg/ha
Dclxwkg/ha - Dry calyx weight kg/ha
Sdykg/ha - Seedyieldkg/ha

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