Nile Valley University Publications
Nile Journal for Agricultural Sciences (NJAS)
(ISSN: 1585 – 5507)
Volume 10, NO. 02, 2025
nilevalley.edu.sd

Response of Roselle (Hibiscus sabdariffa L.) and Soybean (Glycine max L. Merr.) grown as intercropping and sole crop to inter-row spacing under rain-fed conditions in the Blue Nile Region, Sudan

Adlan M. A. Adlan[1], Ali E. Eljak[2], Yasmin A. Aburigal[2] , Eisa Y. A[3] and Amin AA Ibrahim[1]

1 Agricultural research corporation, Damazin Research station, Damazin Sudan**.**
2 Gazira university, faculty of Agricultural sciences, horticultural department, wad medani Sudan.
3 Agricultural research corporation, integrated pest control research center, wad medani Sudan**.**
Correspondent author: adlanma2019@gmail.com

Received : 24. Jul. 2025 **Accepted :29. Sep. 2025** **Published : 23. Nov. 2025**

Abstract

The experiment was conducted at Damazin Research Station Farm during the autumn seasons of 2019 and 2020, to evaluate the effect of inter-row spacing on Roselle and Soybean grown as intercropping and a sole under rain-fed conditions. A 2x2 factorial experiment arrangement in a randomized complete block design (RCBD) was used. The two factors were two inter-row spacing (60 and 80 cm) and planting methods (intercropping and sole cropping). Data collected included growth parameters (plant height and number of branches and yield components. Yield parameters at harvest included Roselle calyces yield, Roselle seed yield and soybean seed yield, all measured in tons per hectare (t ha -1). The Land Equivalent Ratio (LER) was calculated to assess the yield advantage of intercropping. Data were subjected to analysis of variance (ANOVA) using the GenStat computer statistical package. Intercropping resulted in a yield reduction of less than 50% for Roselle calyces, Roselle seed yield and soybean seed yield. The LER values consistently exceeded 1.0, indicating that intercropping was more efficient than sole cropping in resources utilization.

Keywords*: Roselle, Soybean, inter-row spacing, intercropping, sole, Calyces.*

استجابة الكركدي(*Hibiscus sabdariffa* L.) وفول الصويا (*Glycine max* L. Merr.)للزراعة البينية وكمحصول مفرد اووحيد للتباعد بين الصفوف تحت ظروف الامطار في اقليم النيل الازرق بالسودان

عدلان محمد احمد عدلان [1]، ياسمين ادم ابو الرجال [2]، علي الامين الجاك [2]، عيسي ادم يوسف [3] وامبن السر احمد ابراهيم

1 محطة بحوث الدمازين، هيئة البحوث الزراعية، الدمازين السودان

2 قسم البساتين، كلية العلوم الزراعية ، جامعة الجزيرة، ود مدني السودان

3 مركز الادارة المتكاملة للافات، هيئة البحوث الزراعية ، ود مدني السودان

المستخلص

اجريت التجربة في مزرعة محطة بحوث الدمازين خلال موسمي خريف 2019 و 2020 لتقيم تأثير التباعد بين الصفوف علي الكركديه وفول الصويا المزروع كزراعة بينية (مختلطة) ومحصول منفرد تحت ظروف الامطار في اقليم النيل الازرق , السودان. التجربة عامليه من عاملين بتصميم القطاعات العشوائية الكاملة (المسافات بين الصفوف (60 و 80 سم) وطريقتين للزراعة (الزراعة البينية و محصول وحيد). تضمنت البيانات التي تم جمعها معايير النمو والغلة للكركديه وغلة فول الصويا. تضمنت معايير النمو طول النبات وعدد الفروع. تم تسجيل الغلة للكركديه عند الحصاد بما في ذلك الكؤوس وغلة البذور (طن للهكتار $^{-1}$) كما تم تسجيل محصول بذور فول الصويا (طن للهكتار $^{-1}$) تم تقيم ميزة الغلة للكركديه وفول الصويا المزروع كزراعة بينية عن طريق حساب نسبة كفاءة استخدام الارض. خضعت البيانات التي تم جمعها من التجربة لتحليل التباين باستخدام برنامج الكمبيوتر GenStat. كانت نسبة انخفاض الغلة الناتجة من الزراعة البينية في ترتيبي الزراعة البينية بنسبة اقل من 50 % في كؤوس الكركديه وفي انتاج البذور وفي انتاج بذور فول الصويا , وكانت قيم كفاءة استخدام الارض اعلي من 1.0 مما يعني ان الزراعة البينية كانت اكثر كفاءة من الزراعة الوحيدة في استغلال الموارد.

الكلمات المفتاحية : *الكركدي ،فول الصويا ، المسافة بين الصفوف ، الزراعة المختلطة ، زراعة المحصول المفرد ، ماتحت الكاس .*

Introduction

Roselle (*Hibiscus sabdariffa* L.) is an important annual medicinal plant that belongs to the family Malvaceae and is locally known as *"Karkade"*. Roselle is an important cash crop in Western Sudan, particularly in Northern *Kordofan* State, especially in *Elrahad* and *Um-Rawaba* areas (El Naim *et al.,* 2012). The calyces are widely used to prepare herbal drink, cold and warm beverages, and for making jams and jellies (Tsai *et al.,* 2002).The seeds are somewhat bitter but are grounded to a meal for human food in Africa and are roasted as a substitute for coffee (Seiyaboh *et al.,* 2013).

Soybean is a dominant oilseed crop of the United States, accounting for about 90% of the U.S. oilseed production. Soybean is widely used for food, oil, animal feed, industrial uses, and biodiesel in the U.S. The U.S. is the leading producer and the second-largest exporter of soybean globally. In 2020, soybean was planted on 33.4 million ha and had an average yield of 3.78 t ha with production totaling over 112 Mmt (USDA-NRCS, 2022).

Due to the environmental problems of current agricultural systems as well as reduction of the agricultural land, application of new methods in order to minimize these negative effects and to increase the efficiency of land use are often considered in agricultural development programs. One of the most proper management methods in crop production that leads to improvement of efficiency in resource use is the intercropping system (Mahapatra, 2011). This cropping system might provide insurance against crop failure by reducing disease (Fininsa and Yuen 2000) and insect incidence (Girma, *et al.,* 2000) or against unstable market prices by planting two or more crops under intercropping, and thus reducing the risk of unexpected changeable prices. It was shown by many researchers that intercropping of different crops provided important advantages as well as higher profitability than crops grown as sole (Nursima, 2009). However, yield production of crops grown under intercropping depends on the component of the crops selected as well as row arrangements (Lewis *et al.,* 2003). More work of this nature is needed and calling for more research due to the conflicting results obtained by different researchers. Therefore, the objective of this study was to determine best inter-row spacing for Roselle and soybean under intercropping fashion that result a greatest yield and provide better land use efficiency, which could be useful to small farmer's scale under rain-fed conditions in the Blue Nile Region.

Materials and method

The experiment was conducted at Damazin Research Farm during the seasons of 2019 and 2020, to evaluate the effect of different inter-row spacing on Roselle and Soybean grown as intercropping and a sole under rain-fed conditions. The treatments comprised (2x3 factorial in randomized complete block design) of two inter-row spacing's (60 and 80 cm) and two planting methods (intercropping and a sole). These treatments were arranged in randomized complete block design, replicated three times. The land was disc harrowed two times before planting. Each experimental unit included five rows of Roselle 60 or 80 cm between them 4 m long with a net area of 12 or12.8 m^2. Sowing dates was 21th and 27 th July in 2019 and 2020 seasons respectively. Three or four seeds were planted at 30 cm intra-row spacing and then thinned to two plants hole $^{-1}$, two weeks after sowing. Soybean was grown between each two rows of Roselle and then thinned to 5 cm plant spacing. Chemical spraying (Folimate) was applied to control insects populations. Rainfall records were obtained from the Ministry of Agriculture and Natural Resources, of the Blue Nile Region. The data collected included growth and yield parameters for both Roselle and soybean. Five plants of each crop were randomly selected to measure growth parameters, at 50% flowering and again at the end of the season. At harvest, yield was recorded which included calyces and seed yield for Roselle and seed yield for soybean, with all yields reported in tons per hectare t ha $^{-1}$. The yield

advantage of the intercropping system was determined by calculating the Land Equivalent Ratio (LER), a method described by (Mead and Willey, 1980 as cited by Bantie (2014).

$$\text{LER} = \frac{yield\ intercropped\ (main\ crop)}{Yield\ of\ \text{sole}\ cropped\ (main\ crop)} + \frac{yield\ of\ intercropped\ (intercrop)}{yield\ of\ monocropped\ (intercrop)}$$

When LER measures was
LER=1: No advantage of intercropping.
LER <1: Intercropping reduced total yield.
LER>1: Intercropping increases total yield.

All collected data were subjected to an analysis of variance (ANOVA) using the GenStat statistical package, following the procedure outlined by Buysse *et al.,* (2004). A homogeneity test was also performed to compare the data between two growing seasons.

Results

Table 2 showed meteorological data of rainfall (mm) in both seasons at Damazin Research Station. Main rainfall data recorded in season 2019 was higher than that of 2020. Homogeneity test between two seasons was done showed that no significant difference between two seasons, and combined analysis was done.

(Table 3) showed that planting methods and inter-row spacing significantly affected Roselle plant height during both seasons and combined. The heights increase was recorded in the first season compared to the second season. A narrow inter-row spacing and grow Roselle as intercropping with soybean were gave the tallest plants (cm) in both seasons.

Table 4 showed that planting methods and inter-row spacing significantly affected on Roselle number of branches plan $^{-1}$ and combined_in both seasons and combined_except that of planting methods in season one. Wide inter-row spacing and grow hibiscus as a sole cropping were gave the highest number of branches plan $^{-1}$.

Table (5) showed that planting methods was significantly affected on Roselle Calyces yield (ton's ha $^{-1}$) in both seasons and combined analysis except planting methods in season one, while inter-row spacing and interaction were not affected Calyces yield (ton's ha $^{-1}$). Growing Roselle as a sole cropping was gave the highest Calyces yield (ton's ha $^{-1}$)**.**

Table 6 showed that planting methods and inter-row spacing were significantly affected on Roselle seed yield ton's ha $^{-1}$ in both seasons and combined except inter-row spacing in the second season, while interaction was effected only in the second season. Wide inter-row spacing and grow Roselle as a sol cropping were gave the highest seed yield ton's ha $^{-1}$.

Table 7 showed that planting methods was significantly affected on soybean number of branches plan $^{-1}$ just in second season and combined, while inter-row spacing and interaction were not significantly affected on soybean number of branches plan $^{-1}$ except inter-row spacing in second season. Wide inter-row spacing and sowing soybean as a sole cropping gave the highest number of branches plan $^{-1}$.

Table (8) showed that planting methods, inter-row spacing and interaction effect were significant on soybean seed yield (ton's ha $^{-1}$,) except planting methods in the second season and inter row spacing in first season. Close inter-row spacing and sowing soybean as a sole cropping were gave the highest seed yield (ton's ha $^{-1}$).

Table (9) showed that the combined (total) land equivalent ratio (LER %) of Roselle and Soybean intercropping were not significantly influenced by the interaction compare with inter-row spacing. LER measures were greater than 1.0 that means an intercropping is more advantageous than sole cropping in utilizing resources. A combined analysis of data from both seasons revealed that the close inter-row spacing resulted in a significant increase in the land equivalent ratio (LER) [The highest land equivalent ratio (LER %) and combined

analysis of Roselle and Soybean intercropping during both seasons and combined analysis were obtained by 60 cm inter-row spacing].

Discussion

Narrow inter-row spacing and intercropping of Roselle with soybean gave the highest plants height (cm) in the two seasons and combined. This could be due to high competition of plants to light. Supporting evidences were reported by Ramos *et al.* (2011) on Roselle and Mushayabasa *et al.* (2014) on Okra who stated that an increase in planting population markedly would increase plant height. The tallest plants produced by the most densely populated plants might be attributed to the competition for light and other growth resources among the plants that were crowded at the closer plant spacing (Mauryaet *al.,* 2013). Contrasting result obtained by ElNaim *et al.* (2012) who showed that crop density had no significant effect on plant height of Roselle. Yield of Roselle and soybean in two intercropping row spacing was significantly less than Roselle and soybean yield as sole crops, that might be due to the competition between these two crops for the available resources. Similar results were obtained by Akintoye *et al.* (2011) in their work on okra / pumpkin intercropping. From the result of this study, soybean can be intercropped with Roselle, since LER in two inter-row spacing, this was in agreement with the reports of (Olowe and Adebimpe, 2009) who observed, soybean can be intercropped with sunflower, since LER in most plant spacing testing.

In intercropping treatments, the increase in inter-row spacing from 60 cm to 80 cm increase yield of Roselle and Soybean. This increase can be attributed to increased competition in narrow arrangement. As Roselle and Soybean inter-row arrangement decreased from 80 cm to 60 cm, there was an increasing trend in total LER from 1.3, 2.1 and 1.7 to 1.4, 2.7 and 2.1 on season two and combine analysis respectively. This was in agreement with the reports of (Pushpa *et al.,* 2017) who observed increment in total LER as common bean planting density increased from 25% to 100%. Based on the values of total LER, advantage of intercropping Roselle with pigeon pea.

Conclusions

- This study showed that that wide inter-row spacing (80 cm) and grow Roselle as a sole cropping gave the highest number of branches per plan and seed yield ton ha $^{-1}$.
- Growing Roselle as a sole cropping gave the highest Calyces yield in ton ha $^{-1}$.
- Narrow inter-row spacing (60 cm) and grow Soybean as a sole cropping gave the highest seed yield in ton ha $^{-1}$.
- Yield decrease percentage as effected by intercropping in two intercropping arrangements were less than 50% on Roselle Calyces, seed yield and soybean seed yield in ton ha $^{-1}$.
- LER measures were greater than 1.0, that means an intercropping is more advantageous than sole cropping in utilizing resources.

References

Akintoye, H. A.; Adebayo, A. G.; Aina, O. O. (2011). Growth and yield response of okra intercropping with live mulches, Asian *Journal of Agriculture Research*, 5 (2): 146 - 53.

Bantie, Y.B. (2014). Determination of effective spatial arrangement for intercropping of maize and potato using competition indices at south wollo, Ethiopia. International Journal of Research in Agriculture and Food Sciences. 2(8): 9-19.

Buysse, W.; Stern, R.; Coe, R. (2004). Gen Stat Discovery Edition for Everyday Use. ICRAF Nirobi, Kenya. 114 pp.

El Naim, A. M,; Khaliefa, E. H.; Ibrahim, K. A.; Ismaeil, F. M.; Zaied, M. B. (2012). Growth and yield of Roselle (*Hibiscus sabdariffa* L.) as influenced by plant population in Arid tropic of Sudan under rain-fed. *International Journal of Agriculture and Forest*, 2(3): 88-91.

Fininsa, C.; Yuen, J. (2000). Temporal progression of bean common bacterial blight in sole and intercropping, European Journal of plant pathology, 108(6): 485-495.

Girma, H.,; Rao, M.R.; Sithantham, S. (2000). Insect pests and beneficial arthropod populations under different hedgerow intercropping systems in semiarid Kenya, Agro forestry Systems. 50(3): 279-292.

Lewis, W.; Jett Chism, J. S.; Conley, S. P. (2003). Intercropping systems for tomato within a high tunne, Report submitted to Dept. of Horticulture, Missouri Univ. – Colombia: 1-18.

Mahapatra, S. C. (2011). Study of grass-legume intercropping system in terms of competition indices and monetary advantage index under acid lateritic soil of India. American Journal Experimental Agriculture, 1:1-6

Maurya, R. P.; Bailey, J. A.; Chandler, J. S. A. (2013). Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (*Abelmoschus esculentus* (L.) Moench). Am. Journal of Agriculture and Forest, 1(4): 48-54.

Mead, R.; Willey, R.W. (1980). The Concept of a 'Land Equivalent Ratio' and Advantages in Yields from Intercropping. Experimental Agriculture. 16(3): 217 – 228.

Mushayabasa, T.; Kona, D.; Gama, R. (2014). Yield and fruit quality of okra (*Abelmoschus esculentus* L. Moench) in response to plant density. International Journal of Bioscience, 5(1), 449 - 54

Nursima, K.A. (2009). Profitability of intercropping corn with mug bean and peanut, USM. R&D, 1(1): 65 – 70.

Olowe, V. I. O.; Adebimpe, O. A. (2009). Intercropping sunflower with soya beans enhances total crop productivity. Biological Agriculture and Horticulture 26: 365–377.

Pushpa, T. N.; Umesha, K.; Vasundhara, M.; Ramachand rappa, B. K.; Sreeramu, B. S.;.Srikantaprasad, D. (2017). Intercropping of Roselle with Red Gram and Nipped Castor is Beneficial to Dry Land Farmer. International Journal of Current Microbiology and Applied Science. 6(9): 2179-2188.

Ramos, D. D.; Carmoviera, M.; Zarate, N. A. H.; Yamanto, N. T.; Carnevali, T. O.; Souza, N. H. (2011). Spacing's between plants with chicken manure in Roselle crop. Maringa., 33(4): 695-700.

Seiyaboh, E. I.; Oku, I. Y.; Odogbo, O. M. (2013). Isolation and Identification of Food-Borne Micro Flora from Zobo (A Nigerian Drink) Prepared from The Calyces Of *Hibiscus SabdariffaL*. (Malvaceae). The International Journal of Engineering and Science (IJES) 2: 1805-2319.

Tsai, P. J.; McIntosh, J.; Pearce, P.; Camden, B.; Jordan, B. R. (2002). Anthocyanin and antioxidant capacity in Roselle (*Hibiscus sabdariffa* L.) extract. Food Research International. 35: 351-6

USDA-NRCS, Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available online. https://soilseries.sc.egov.usda.gov/OSD_Docs/B/BOSKET.html Last accessed [04/ 29/2022].

Table. 1 Theoretical plant populations hectare $^{-1}$ of the two inter-row spacing's

inter-row (cm)	Roselle ha^{-1}	Soybean ha $^{-1}$	Plants ha $^{-1}$ (total)
80	83,333	250,000	333,333
60	111,111	333,333	444,444

Table 2. Metrological data of rainfall (mm) at two seasons 2019 and 2020

Months	2019	2020
May	78.1	32.6
June	128.3	82.6
July	220.5	175.0
August	242.4	196.9
September	119.6	74.1
October	81.0	35.5
Mean	869.9	596.7

Table 3. Effect of intercropping and inter-row spacing on Roselle plant height (cm)

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Means	60	80	Means	60	80	Means
Sol	94.8	81.2	88.0	77.7	83.0	80.3	86.3	82.1	84.2
In. C.	98.3	91.2	94.8	85.3	88.7	87.0	81.8	89.9	90.9
Means	96.6	86.2		81.5	85.8		89	86	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	*	1.54	2.5	*	0.83	1.4	*	0.36	9.4
Spacing	*	1.29		*	0.69		*	0.47	
Interaction	NS	4.6		NS	4.5		NS	5.9	

Table 4. Effect of intercropping and inter-row spacing on Roselle number of branches plan $^{-1}$

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Mean	60	80	Mean	60	80	Mean
Sol	10.2	13.7	11.9	10.2	12.0	11.1	10.2	12.8	11.5
In. C.	7.0	10.2	8.6	6.9	7.8	7.3	6.9	9.0	7.9
Mean	8.6	11.9		8.6	9.9		8.5	10.9	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	NS	1.1	14.6	*	0.73	3	*	0.56	14.8
Spacing	*	0.86		*	0.16		*	0.47	
Interaction	NS	4.7		*	0.75		NS	4.7	

Table 5. Effect of intercropping and inter-row spacing on Roselle Calyces yield ton's ha $^{-1}$

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Mean	60	80	Mean	60	80	Mean
Sol	0.23	0.25	0.24	0.25	0.29	0.27	0.24	0.27	0.25
In. C.	0.18	0.19	0.19	0.21	0.24	0.23	0.19	0.23	0.21
Mean	0.20	0.22			0.26		0.22	0.24	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	*	0.008	10.4	*	0.002	12.8	*	0.004	6.9
Spacing	NS	0.01		NS	0.01		NS	0.01	
Interaction	NS	5.9		NS	4.7		NS	4.4	

yield decrease percentage as effected by intercropping were 20, 15 and 16 % at two seasons and combine analyses respectively

Table 6. Effect of intercropping and inter-row spacing on Roselle seed yield ton's ha $^{-1}$

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Mean	60	80	Mean	60	80	Mean
Sol	0.43	**0.57**	0.50	0.24	**0.31**	0.28	0.37	**0.41**	0.39
In. C.	0.23	0.33	0.28	0.16	0.20	0.18	0.20	027	0.23
Mean	0.33	0.45		0.20	0.26		0.28	0.34	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	**	0.04	7.4	***	0.001	7.4	*	0.02	17.6
Spacing	**	0.02		NS	0.01		*	0.01	
Interaction	NS	0.1		*	0.009		NS	3.3	

yield decrease percentage as effected by intercropping were 40, 35 and 31% at two seasons and combine analyses respectively.

Table 7. Effect of intercropping and inter-row spacing on soybean number of branches plan $^{-1}$

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Mean	60	80	Mean	60	80	Mean
Sol	11.8	12.8	12.3	14.3	17.2	15.8	13.1	15	14
In. C.	8.1	8.4	8.3	7.4	8.3	7.9	7.8	8.4	8.1
Mean	9.9	10.6		10.9	12.8		10.4	11.7	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	NS	3.9	11.5	*	0.3	9.3	*	0.8	21.5
Spacing	NS	4.1		*	0.6		NS	0.6	
Interaction	NS	3.9		NS	5.5		NS	1.6	

Table 8. Effect of intercropping and inter-row spacing on soybean seed yield ton's ha $^{-1}$

Planting Methods	Inter-row spacing (cm)								
	Season 2019			Season 2020			Combine		
	60	80	Mean	60	80	Mean	60	80	Mean
Sol	1.4	1.0	1.2	1.3	0.6	0.9	1.3	0.8	1.1
In. C.	0.6	0.7	0.7	0.5	0.7	0.6	0.6	0.6	0.6
Mean	**1.0**	**0.9**		0.9	0.6		1.0	0.8	
Statistics									
	Sig.	SE ±	CV%	Sig.	SE ±	CV%	Sig.	SE ±	CV%
Methods	*	0.08	10.8	NS	0.1	11.1	*	0.09	19.8
Spacing	NS	0.1		*	0.03		**	0.02	
Interaction	*	0.1		**	0.08		***	0.09	

yield decrease percentage as effected by intercropping were 41, 40 and 45% at two seasons and combine analyses respectively.

Table 9. land Equivalent Ratio (LER%) of Roselle and Soybean intercropping

intercropping	Season 2019		Season 2020		Combine	
	60	80	60	80	60	80
1	1.4		2.7		2.1	
2		1.3		2.1		1.7
Statistics						
Sig.	NS		NS		*	
SE ±	0.09		0.2		0.06	
CV%	9.`		11		12.6	