RESEARCH ARTICLE Bhartiya Krishi Anusandhan Patrika

Weed Competition and Performance of Sorghum and Groundnut Intercrop as Influenced by Row Orientation and Arrangement

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10.18805/BKAP717

ABSTRACT

Background: Intercropping and row arrangement represent a dynamic frontier of research and practical application, influencing resource allocation, weed competition and overall crop productivity in a modern agro ecosystem. This study aimed to investigate the impact of row orientation and arrangement on weed competition and crop performance within the Sudan savannah ecology of Nigeria during the 2018 rainy season.

Methods: A field experiment was conducted at BUK (Latitude 11°58′N and Longitude 8°25′E) and Minjibir (Latitude 12.14590N and Longitude 0.866′4850E), utilizing two orientations (East-West and North-South) and seven sorghum: groundnut row arrangements (1:1, 1:2, 2:1, 2:2, 3:3, 2:4 and 4:2). A randomized complete block design with three replications was used, with simultaneous cultivation of SAMSORG 40 sorghum and SAMNUT 24 groundnut varieties.

Result: The 2:1 row arrangement exhibited the lowest weed density (23.2 and 31.1 m^{-2}) and dry weight (408.6 and 438.2 kg ha^{-1}). East-West orientation reduced weed density by 24.5% at BUK and 20.8% at Minjibir. North-South row orientation significantly increased sorghum grain yield by 17.7% and reduced groundnut kernel yield by 9.37%. Higher sorghum yield (699.6 and 773. 7 Kg ha^{-1}) was observed with 2:1 whereas the 1:2 arrangement yielded more groundnut kernels (329.2 and 338.1 kg ha^{-1}). East-West orientation and the 2:1 row arrangement suppressed weed growth and recorded higher yields.

Key words: Crop performance, Intercropping, Weed competition, Weed density, Yield.

INTRODUCTION

Intercropping is gaining recognition as an efficient and cost-effective agricultural practice. It not only boosts production per unit of land and time but also enhances resource utilization efficiency while reducing the adverse impact of weed competition. This holds significant promise for improving the economic well-being of farmers in sub-Saharan Africa. Currently, there is a growing interest in intercropping, particularly among small-scale farmers. This enthusiasm stems from the diverse needs of these farmers and the realization that mono-cropping systems often yielded insufficient farm income. Consequently, there is a strong desire for options that enable the simultaneous cultivation of two or more crops on the same piece of land. This approach aims to enhance overall agricultural productivity, especially for small landholders and bolster the ability of crops to compete effectively against weeds (Chunfeng *et al*., 2021).

The world production of sorghum (in 2022) stood at 57.58 million tons from 40.76 million ha with an average yield of 1.4126 tons ha^{-1} while for groundnut it was 54.2 million tons from an estimated are of 30.53 million ha with an average yield of 1.776 tons ha^{-1} (FAO, 2023). Nigeria is among the world's largest sorghum and groundnut-producing countries and a leading sorghum producer in terms of total production in Africa. The sorghum productivity in the country (in 2022) mounted to 6.8 million tonnes from 5.7 Million ha with an average yield of 1.19 tonnes ha^{-1} while for groundnut it was 4.28 million tons from an estimated area of 34 million ha with an average yield of 1.266 tons ha^{-1}. Sorghum Cereal legume intercropped has been in practice in Nigeria for decades. Sani *et al.* (2011) reported that 2 rows of maize: 2 rows of sorghum recorded higher maize (4428 kg ha^{-1}) and sorghum (2123.05 kg ha^{-1}) grain yield compared to 2rows of maize:1 row of sorghum which produced 2519 kg ha^{-1} for maize and 1705 kg ha^{-1} for sorghum. Similarly, Alabo *et al.* (2015) reported that 2 rows of sorghum: 1 row of soybean out yielded 1 row of sorghum:1 row of soybean by 83% while soybean yield was 93.3% higher in 1 sorgum:2 rows of soybean than in 1 row of sorgum: 1 row of soybean. In a reviewed paper, Nweke (2017) noted that the Maize/Cowpea intercropping system significantly increased forage dry matter yield compared to maize and cowpea sole crops. In a sorghum/cowpea intercropped, Afe (2020) observed the lowest grain yield of sorghum (1,160.84 kg/ha) and cowpea (583.38 kg/ha) from 100 sorgum: 100 cowpea and 100 sorghum:25 cowpea population ratios, respectively.

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How to cite this article: Abba, A.B., Lado, A., Hussaini, M.A. and Buhari, F.Z. (2024). Weed Competition and Performance of Sorghum and Groundnut Intercrop as Influenced by Row Orientation and Arrangement. Bhartiya Krishi Anusandhan Patrika. DOI: 10.18805/BKAP717.

Submitted: 21-02-2024 **Accepted:** 31-05-2024 **Online:** 11-06-2024

Weeds are an important yield-limiting factor in crop production in most sub-Saharan countries of the world. Weed control accounts for over 65% of the farmer's income, resources, labor and time in crop production. Due to competition with crop for environmental resources necessary for growth, weeds cause variable crop yield losses which can be as high as 100% depending on the crop type and environment (Chunfeng *et al*., 2021). Weeds decrease crop quality, cause uneven maturation, make harvesting difficult and increase the incidence and severity of other pests (Hamidreza *et al*., 2014). To reduce yield losses and increase the level of food security, farmers in the study area use various weed management strategies. However, most of the weed management options practiced today are associated with one problem or the other. The use of herbicides to control weeds has been well adopted in many localities, but this method of weed management has been associated with many environmental issues and human health (Lado *et al*., 2018). Building up of herbicide resistant weeds is also one of the major challenges with the use of herbicides. Manual hoe weeding is the oldest method of weed management in many parts of Africa but it is costly, time-consuming and practicably impossible in commercial agriculture due to a shortage of labour at periods of high demand. Soil tillage is expensive due high cost of fuel and can be another source of environmental pollution due to Co_2 emission (Sauerbeck, 2001). Frequent soil tillage is associated with the destruction of soil texture and structure leading to the problems of soil erosion. There is a need therefore to look for alternative ways of weed management that are cost effective, environmentally friendly and compatible with our local agronomic practices and systems. Crop diversification through the use of various row arrangements and orientation in intercropping systems has been a promising way to improve crop competitive behaviour against weed and to improve its resilience to environmental and biotic stresses (Wood *et al,* 2015; Bhuva *et al*., 2017**;** Sharmili *et al*., 2023).

Light constitutes a vital resource subject to competition between crops and weeds. Enhancing light absorption by the crop serves as a means to suppress weed growth. On the flip side, excessive shading from neighbouring plants is reduced, creating conditions conducive to more efficient photosynthesis and ultimately boosting crop yields. This also facilitates or improved air circulation within the inter-row spaces, enhancing gas exchange and mitigating excessive humidity (Ben *et al*., 2011). Inappropriate row direction may result in rapid weed growth and crop yield losses. A possible way to reduce light interception by weed is by manipulating the row arrangement and its orientation (Amar and Bhagirath, 2015). Literature have shown that weed growth and development can be reduced by intercropping (Orluchukwu and Udensi, 2013) Therefore, manipulation of crop row arrangement and orientation in intercropping system can be used as an option for managing weed problems through non-chemical methods (Vandermeer, 1992). This study was designed to evaluate the efficacy of row arrangement and orientation in reducing weed infestation and increase crop yield in sorghum-groundnut intercrops.

MATERIALS AND METHODS

The experiment was conducted during the wet season of 2018 at Teaching and Research Farm, Bayero University, Kano (Latitude 11°58′N and Longitude 8°25′E) and Institute for Agricultural Research (IAR) Farm located at Wasai (Latitude 12.1459°N and Longitude 0.866′485°E), Minjibir Local Government Area of Kano State. The soil pH of both locations were acidic in nature. The organic carbon composition was very high at both locations. The total nitrogen at BUK was moderate but very high at Minjibir, whereas available phosphorus (P) was found to be low from both locations. Soils at BUK had low Ca and K with moderate Mg and very low Na while at Minjibir, there was moderate Ca and Mg with very low K and Na. The CEC of soil from both sites were low.

The experiment comprised of two row orientations (East-West or North-South) and seven (7) row arrangements (1:1, 1:2, 2:1, 2:2, 3:3, 2:4 and 4:2). The row arrangements of the intercropping system were; 1:1-1 row of sorghum alternated with 1 row of groundnut giving a final plant population of 50% of each crop in the mixture, 1:2- 1 row of sorghum alternated with 2 rows of groundnut with a final population of 25% sorghum and 75% groundnut, 2:1- 2 rows of sorghum alternated with 1 row of groundnut with a final population of 75% sorghum and 25% groundnut, 2:2- 2 rows of sorghum alternated with 2 rows of groundnut giving a final population of 50% of each crop, 3:3-3 rows of sorghum alternated with 3 rows of groundnut giving final population of 50% of each crop, 2:4-2 rows of sorghum alternated with 4 rows of groundnut giving final population of 25% sorghum and 75% groundnut and 4:2-4 rows of sorghum alternated with 2 rows of groundnut giving a total population of 75% sorghum and 25% groundnut. Thus, the mixture was a replacement series. The treatments were factorially combined and laid out in randomized complete block design replicated three times. Sorghum (SAMSORG - 40 (ICSV 400)) and groundnut (SAMNUT- 24) seeds were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Kano station and Institute of Agricultural Research (IAR Samaru Zaria, respectively. The land was cleared, harrowed and made into ridges 75 cm apart when the rain was established.

Sorghum was sown at 75 cm × 25 cm inter and intra-row spacing, respectively using a seed rate of 5 seeds per hole. Subsequently, thinning was conducted, reducing the number of seedlings to 1 per stand at two weeks after sowing (2WAS). Groundnut was sown with an inter-row spacing of 75 cm and an intra-row spacing of 30 cm, with 3 seeds planted per hole. After two weeks of sowing (2WAS), thinning was performed, retaining 2 plants per stand.

Weed management was carried out manually, utilizing hoe weeding. The first weeding operation was executed at 3 WAS, followed by a second weeding session at 6 WAS for both crops. Fertilizer was applied to sorghum at a rate of 64 kg/ha for N (nitrogen), 30 kg/ha for P_2O_5 (phosphorus) and 30 kg/ha for K2O (potassium). This was applied in two stages: an initial application of 30 kg ha^{-1} for N, 30 kg ha^{-1} for P_2O_5 and 30 kg ha^{-1} for K2O as a basal treatment during sowing, using NPK 15:15:15. The remaining 34 kg ha^{-1} of nitrogen was applied at 4 WAS by side placing urea (containing 46% nitrogen). For groundnut, a basal application of 20 kg ha^{-1} for N, 54 kg ha^{-1} for P_2O_5 and 20 kg ha^{-1} for K2O was carried out. This involved using 20 kg ha^{-1} of N, 20 kg ha^{-1} of P_2O_5 and 20 kg ha^{-1} of K_2O through NPK 15:15:15, alongside an additional 34 kg ha^{-1} of P_2O_5 from SSP (superphosphate, containing 18% P_2O_5). Both sorghum and groundnut crops were manually harvested at their respective maturity stages. For sorghum, it was when the leaves became yellowish in colour and the seed became hard that could not be crushed with a finger. Groundnut was harvested when the leaves turned yellow and by examination of the pod inside the shell which turned brownish in colour.

Weed cover score was assessed at physiological maturity where a 1m^2 quadrat was placed randomly in each plot and marked out. Weed cover within the quadrats area was scored according to the standard scale of; 0= No Weed, 1= Moderately Weedy, 2= Very Weedy and 3= Highly Weedy (Komboik *et al*., 2003). Weed density was determined by counting the number of each weed within the quadrat in each plot and was calculated as follows;

$$\text{Weed density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrat use}}$$

Weeds within the 1m^2 quadrant were manually harvested from the ground level and samples were levelled and oven dried to a constant weight at 70°C after which the samples were weighed and recorded to obtain the dried weight (Rao, 2000). Sorghum grain yield and groundnut kernel yield were obtained from the net plot after sun drying and extrapolated to kg ha^{-1}. One thousand sorghum grains were counted and weighed using balance graduated in gm. Kernel weight was obtained by counting and weighing 100 kernels using the same machine. All these (grains and kernel) were extrapolated to kg ha^{-1}

Statistical analysis

Data generated were subjected to Analysis of Variance (ANOVA) using JMP Pro 13. Significantly different treatment means (<0.05) were compared using Student Newman Keuls (SNK).

RESULTS AND DISCUSSION

Row orientation had no effect on the weed cover score at both locations (Table 1). However, North-South orientation significantly (P<0.001) recorded higher weed density and weed dry weight while East-West orientation had the lowest in both locations. The 1:2 arrangements significantly (P<0.001) recorded the highest weed cover, weed density and dry weight in both locations. Significantly lower weed cover score, weed density and dry weight were observed from 2:1 arrangements at both locations. The interactions between row orientation and arrangement on weed cover score, weed density and weed dry weight was not significance from both locations.

Row orientation had no significant effect on seed weight in both locations (Table 2). Row arrangement of 1:2 had a heavier 1000 seeds weight which was statistically different (P<0.001) from 2:2 and 3:3 arrangements but similar to other raw arrangements at BUK. At Minjibir 2:1 and 4:2 arrangements recorded significantly (P<0.001) higher seed weight than other row arrangements. East-West orientation significantly recorded higher grain yield than North-South orientation at Minjibir while a non-significant effect was observed at BUK. The results also indicated that 2:1 and 4:2 arrangements significantly (P<0.001) produced higher grain yield compared to other arrangements at BUK. A similar trend was observed at Minjibir. The interactions between the raw orientation and arrangement of grain yield were not significant.

Row orientation did not affect kernel weight in the sorghum-groundnut intercropping system in both locations (Table 3). However, North-South orientation significantly recorded higher kernel yield than East-West in both locations. The 3:3 raw arrangements significantly (P<0.001) produced a heavier kernel than the 1:2 arrangement at BUK. However, at Minjibir, row arrangement had no effect on kernel weight. Significantly higher kernel yield was obtained from 1:2 and 2:4 arrangements in both locations. The least kernel yield was observed from the 2:1 and 4:2 arrangements. The interactions between row orientation and arrangement on kernel weight and yield of groundnut in sorghum-groundnut intercropping system were not significant from both locations.

Higher weed density and weed dry weight recorded on North-South over East-West indicated that this type of orientation provided enough solar radiation which enabled the weed to grow, develop their shoot and compete favourably with crops in terms of mineral materials. This implied that East-West orientation suppressed weed growth and development and can therefore be used as a tool in weed management in the study area. An investigation by Dimitrios *et al*. (2010) reported a significant difference in weed dry matter and weed density in maize-legume crops. Because of its higher weed density, North-South orientation recorded higher weed dry mater than East-West orientation implying that it enhanced weed growth and cannot be used as a tool for weed management. This could be due to inter specific competition that occurred between the crops and weeds which increased the rate of survival and absorption of nutrient resources. Similarly, Kumar *et al.*

(2022) noted appreciable decrease on crop performance due to competition for environmental.

Current findings revealed that the 1:2 row arrangement enhanced weed growth better than other arrangements. This means that this arrangement suits the development of the weed through better competition with the crops. This pattern of arrangement recorded higher weed cover and weed dry weight possibly because it provided weed with

Table 1: Weed cover score, weed density and weed dry weight in sorghum-groundnut intercrop as influenced by row orientation and arrangement at BUK and minjibir in 2018 raining season.

Treatments	BUK			Minjibir		
	Weed cover score	Weed density (m^2)	Weed dry weight (kg/ha)	Weed cover score	Weed density (m^2)	Weed dry weight (kg/ha)
Row orientation (RO)						
East-West	1.3	24.3b	486.8	1.4	25.1b	415.7b
North-South	1.5	32.1a	530.0	1.6	31.7a	664.7a
P value	0.583	0.044	0.407	0.320	<.001	<.001
S E±	0.085	1.549	51.300	0.141	1.606	33.410
Row arrangement (RA)						
1:1	1.8a	26.6ab	565.0	1.3b	28.3	448.3b
1:2	2.0a	34.0a	508.6	1.8a	30.5	666.6a
2:1	1.0b	23.1b	408.3	1.0b	26.1.	438.3b
2:2	1.0b	29.5ab	437.6	1.6a	27.6	541.6ab
3:3	1.8b	28.5ab	534.1	1.3b	28.8	610.0ab
2:4	1.8a	27.0ab	520.0	1.8a	26.6	503.3ab
4:2	1.0b	29.1ab	585.0	1.5ab	31.0	573.3ab
P value	<001	0.042	0.509	0.039	0.068	0.050
S E±	0.160	2.897	95.900	0.264	3.005	62.500
Interaction						
RO × RA	0.226	4.097	88.3	0.373	4.249	73.2

Means followed by the same letters in a column are not significantly different at 5% level of probability using SNK. BUK= Bayero University, Kano.

Table 2: Seed weight and grain yield of sorghum as influenced by row orientation and arrangement in sorghum-groundnut intercropping system at *BUK and minjibir in 2018 raining season.

Treatments	BUK		Minjibir	
	Seed weight (g)	Grain yield (kg ha^{-1})	Seed weight (g)	Grain yield (kg ha^{-1})
Row orientation (RO)				
East-West	28.7	412.7	28.4	525.1a
North-South	27.9	425.0	30.1	432.1b
P value	0.252	0.511	0.233	<.001
S E±	0.700	18.520	0.953	17.260
Row arrangement (RA)				
1:1	27.8ab	398.1b	26.4	486.1b
1:2	29.4ab	189.3c	29.7	193.3c
2:1	32.1a	699.6a	30.7	773.7a
2:2	25.9bc	398.1b	32.7	481.5b
3:3	23.1c	382.7b	26.6	481.5b
2:4	29.2ab	179.0c	31.4	185.2c
4:2	31.1ab	685.2a	27.0	753.1a
P value	<.001	<.001	0.094	<.001
S E±	1.26	34.66	1.78	32.280
Interaction				
RO × RA	2.409	49.01	3.567	45.65

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using * = Bayero University, Kano.

ample opportunity of getting enough solar radiation and other environmental resource necessary for growth. This implied that this pattern of row arrangement enhanced weed growth and cannot be used as a tool for weed management in intercropping systems. Seran and Brintha (2010) reported that intercropping gave clear evidence of better weed control by providing more competitive effect against weed either in time or space than those monocropping. Double rows of sorghum and single row of groundnut provided a complete canopy cover which might have prevented the weeds from getting solar radiation. This could have explained the reason why 2:1 row arrangement recorded lower weed density and dry weight. This suggested that this kind of row arrangement suppressed weed growth and could be used as a mechanism of weed control. This finding contradicted that of Choudhary *et al.* (2014) who reported that intercropping maize with cowpea at a row proportion of 1:2 helps in suppressing weed growth due to the shading effect and competition stress created by the cowpea canopies. Likewise, as reported by Fakkar and El-Dakkak (2015) effective crop sequences can lead to a reduction in weed densities during crop emergence. This reduction played a crucial role in minimizing yield losses and curbing the shift towards weed species that are challenging to manage in the long term.

Higher sorghum yield observed on East-West orientation at Mijibir could be due to the angle of the crop sown being best suited to the direction of energy received for good utilization of assimilate which is necessary for production. This row orientation provided the best opportunity for the crop to exploit the environmental resources necessary for growth. This corroborated with the findings of Evers and Bastiaans (2016) who reported that the competitive ability of crops can be increased by a good crop spatial orientation. The outstanding performance of East-West crop orientation over North-South could also be due to excellent weed control which minimized competition with crops by increasing yield as reported by Hamidreza *et al.* (2014).

Good row orientation of sorghum permitted the canopy to intercept enough light hence increasing vegetative growth and grain yield. This could also be related to the benefit of nutrients and contribution to soil moisture retention and reduced competition between sorghum and groundnut. The consequences of all these were manifestations of heavier seed and high grain yield. Crop species with contrasting nutrient requirements are more likely to be benefited from inter-crop mixtures as reported by Gbehounou and Adango (2003).

Heavier seed and higher sorghum grain yield obtained from 2:1 arrangements could be due to the benefit the cereal derived from alternating planting between legumes for nitrogen. It could also be related to the contributing benefit of soil moisture conservation due contributing effect of sorghum that prevented wind speed and the groundnut which covered the soil and prevented evapotranspiration. All these created favorable conditions for photosynthesis and assimilate translocation to the sink leading to the development of heavier seed and high grain yield of sorghum. In little millet - pigeon pea intercrop, Sharmali *et al.* (2023) reported higher millet grain in 6:1 compared to other intercrops. However, our findings contradicted that of

Table 3: Kernel weight and yield of groundnut as influenced by row orientation and arrangement in sorghum-groundnut intercropping system at *BUK and minjibir in 2018 raining season.

Treatments	BUK		Minjibir	
	Kernel weight (g)	Kernel yield (kg ha^{-1})	Kernel weight (g)	Kernel yield (kg ha^{-1})
Row orientation (RO)				
East-West	31.3	172.3b	27.5	239.6b
North-South	31.2	256.9a	27.3	264.4a
P value	0.615	<.001	0.662	0.005
S E±	0.13	10.170	0.335	7.040
Row arrangement (RA)				
1:1	30.5b	185.2bc	28.3	261.7b
1:2	31.6a	329.2a	27.1	338.1a
2:1	30.8ab	148.1cde	27.9	163.7c
2:2	31.3ab	181.4bcd	26.3	264.9b
3:3	31.8a	209.9b	27.5	257.6b
2:4	31.5ab	308.6a	26.6	324.2a
4:2	31.2ab	135.8cde	28.0	154.0c
P value	0.012	<.001	0.249	<.001
S E±	0.247	19.030	0.627	13.170
Interaction				
RO × RA	0.49	26.91	0.34	24.02

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using SNK. * = Bayero University, Kano.

Choudhary *et al.* (2014) who reported that maize grain yield was higher at a 1:2 planting pattern than cowpea. Our finding also disagreed with Kumar *et al.* (2022) who reported that sole cropping significantly recorded higher leaf yield of Palak (Beta vulgaries) compared to onion Palak intercrops in different arrangements.

Orientation of the crop in the North-South direction recorded heavier groundnut kernel weight and yield per hectare. This could be due to proper utilization of the environmental necessary for growth as reported by Hamidreza *et al*. (2014). Orienting sorghum in a North-South direction served as a windbreak reduced the rate of moisture loss through evapotranspiration and enhanced the growth of groundnut. The groundnut was also able to get enough sunlight because the sorghum varieties were short stature and lower leaves tended to get dry creating a space for light to pass through and rich the groundnut. This showed the level of compatibility of this cropping mixture in this study. Our finding did not agree with Tenywa *et al*. (2016) who reported that East-West row orientation resulted in a greater groundnut yield by up to 50%, than those facing North-South in sorghum groundnut intercropped at Uganda. Research by Kuldeep and Sharma (2019) also reported that sowing in a North-South direction resulted in a higher wheat grain yield than sowing in an East-West orientation. However, in Zimbabwe, Haripo *et al.* (2023) have reported higher cowpea grain in East-west orientation than in north-south orientation under sorghum-cowpea intercropped.

CONCLUSION

The study evaluated the effect of row arrangement and orientation on weed competition and performance of sorghum-groundnut intercrops in the Sudan Savanna of Nigeria. The findings of this study showed that, regardless of planting pattern and row orientation, sorghum-groundnut intercropping at 2:1 helped in weed control and had yield advantages and exploitation of the environmental resources as opposed to other intercropping systems. This arrangement can now be considered as the cost-effective and environmentally friendly way of weed management in the study area. North-South sowing orientation with an arrangement proportion of 2:1 for sorghum and 1:2 for groundnut should be adopted. These findings provide valuable insights for farmers in similar agro-ecological contexts, facilitating resource-efficient and sustainable intercropping practices.

ACKNOWLEDGEMENT

I would like to thank the management of the Centre for Dryland Agriculture (CDA, BUK) and the technical staff of the Department of Agronomy, Bayero University of Kano, Nigeria.

Conflict of interest

The authors declare no conflict of interest.

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