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Research paper

Effect of Alley Cropping Microclimate and Water Use on Growth and Yield of Groundnut and Maize on Clay Soils

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ABSTRACT

The objective of this study was to investigate the influence of modified microclimate in eight-meter wide alleys on growth and yield of groundnut and maize under the shade of *Acacia ampliceps* and *Acacia stenophylla* trees in the Gezira Research Station which is characterized by cracking heavy clay soils of low organic and N content. Groundnut and maize crops were evaluated for growth and yield performance by laying out sample plots at southern, central and northern parts of the alleys and at control plots. Due to microclimatic modifications in the alleys, the yield of both crops in the alleys significantly (p=0.01) exceeded the control. It was observed that the alley crop yield performs better under *A.ampliceps* having transmitted radiation of about 64%, which is relatively higher than *A.stenophylla* (56%). Groundnut increased by 14 and 6 % in the *A.ampliceps*-alley and *A.stenophylla*-ally, respectively. On the other hand, maize yield increased by 27 and 15 % in the *A.ampliceps*-alley and *A.stenphylla*-ally, respectively. The results indicated that the competition for light was the major contributing factor toward the reduction of growth and yield of maize crop. Alley cropping plots consumed less water ($571m^3$) than the control ($805m^3$). Water was saved in the ampliceps-alley by 34 and 33 % and in stenophylla-alley by 24 and 24% for groundnut and maize, respectively.

Keywords: Irradiance, semi –arid, acacia stenophylla, eevapotranspiration, water use

تأثير المناخ الموضعي في زراعة الممرات وكفاءة استخدام مياه الري علي نمو وانتاجية محصولي الفول السوداني والذرة الشامية في الاراضي الطينية

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أجريت هذه الدراسة لمعرفة تأثير العناصر المناخية المختلفة على نمو وإنتاجية الفول السوداني والذرة الشامية في نظام زراعة الممرات. اجريت التجربة في محطة بحوث الجزيرة والتي تتميز بتربه طينيه ثقيلة متشققه، منخفضة النتروجين والمادة العضوية. هدفت هذه الدراسة إلى معرفة تأثير المناخ المحسن في الممرات على نمو وإنتاجية الفول السوداني والذرة الشامية. الاختلافات في درجة الحرارة العليا، الرطوبة النسبية، سرعة الرياح والإشعاع تحت ظل شجرتي الامبليسبس والإستنوفيلا. تمّ تقييم نمو وإنتاجية الفول السوداني والذرة الشامية بأخذ عينات من جنوب، وسط، وشمال الممر وكذلك الشاهد. هنالك انخفاض ملحوظ في سرعة الرياح، درجة الحرارة، والإشعاع بينما شهدت الرطوبة النسبية إرتفاعاً داخل الممرات. تبعاً لتحسين المناخ داخل الممرات ازدادت إنتاجية المحصولين معنوياً مقارنةً بالشاهد. انخفاض الإنتاجية في الذرة الشامية في الجزء الشمالي عوضت كلياً بزيادة الإنتاجية في الجزئين الجنوبي والأوسط من الممر. أوضحت النتائج أنّ المنافسة على الضوء هي العامل المؤثر في ذلك. كما لوحظ أداء افضل للمحصولين داخل ممر الامبليسبس الذى حصل على إشعاع بحوالي 64 % وهو إشعاع أعلى نسبياً من الإشعاع داخل ممر الإستنوفيلا الذى يقدر بحوالي 56 %. زادت إنتاجية الفول السوداني بنسبة 14 و 6 % في ممر الامبليسبس والإستنوفيلا على التوالي. من جهةٍ أخرى زادت إنتاجية الذرة الشامية بنسبة 27 و 15% في ممر الامبليسبس والإستنوفيلا على التوالي ايضاً. إضافةً إلى ذلك تمَ قياس مياه الري المستخدمة في ممرات الشجرتين لمحصولي الفول السوداني والذرة الشامية. كان هنالك فرق معنوي في استهلاك المياه بين نظام زراعة الممرات والشاهد. استهلك 517 متر مكعب من المياه في الزراعة بين الممرات الشجرية مقارنةً بحوالي 805 متر مكعب استخدمت لري الشاهد. وفر ما مقداره 34-33 % في ممر الامبليسبس 24-24 % في ممر الإستنوفيلا عن محصولي الفول السوداني والذرة الشامية على التوالي.

كلمات مفتاحية: الاشعاع، شبه جاف، الاكيشيا ستينوفيلا، البخر نتح، استخدام المياه

Introduction

Historically, in Sudan as in most of the third world countries, trees grow naturally as a gift from the All Mighty God without or with limited intervention from people. Not only that, but human-beings intentionally or without awareness constitute a major threat to the well being of the trees and consequently to environment. Agroforestry as a modern science is a new theme in Sudan. However, in practice it is an old fashion of traditional agriculture. The shouting example for that is the integrated system of production in the gum belt in western Sudan where traditional crops are grown with the indigenous tree gum Arabic – producing tree *Acacia senegal* which naturally grows in that habitat. Moreover, exotic trees were introduced to Sudan and were successfully grown with field crops like wheat and faba been and they gave very encouraging results (Shapo and Adam, 2008). Crops production in Sudan focuses mainly on pure-stand crop production neglecting the participation of other resources like trees in that process. During the period from 1987 to 2002, of the total production in this country, the Gezira scheme contributed 58 % of cotton, 46 % of wheat, 23 % of groundnut and 12 % of sorghum (SCC, 1993). Sand movement towards the north western part of the Gezira irrigation scheme threatens that part. An irrigated sand blocking shelter belt *Eucalyptus microtheca* is used to protect canals and crop. Wind speed over eroded land was increasingly higher than that over irrigated cotton land. Both these values were considerably higher than those reported from the nearest meteorological stations. Of the two prevailing winds, of which the summer (SW) wind is perpendicular to the belt. Efforts to control the moving sand in the source area should be joined with those made at the borders of agricultural land (Mohammed *et al.*, 1999).

Groundnut (*Arachis hypogaea*) is one of the major rotational crop in the Gezira scheme. It was introduced to the Gezira scheme in the sixties of the last century. Besides its many industrial and other uses, it is a leguminous crop which can replenish the Gezira soil through nitrogen fixation. In addition it is a rich and palatable animal feed. Maize (*Zea mays* L) used to be a minor crop in the past and the area under it seldom exceeds 500 feddan. The crop has a wide range of usage both as food and feed.

Materials and methods

Experimental site:

An alley-cropping study area was established in 2006 at Gezira Research Station (GRS), 189 km south of Khartoum, Sudan (latitude 14˚ 23' N, longitude 29˚ 33' E and 405 meter above sea level). The soil type was typically clay soil characterized by its high clay content (58-66%). It is also high calcareous alkaline soil, with pH of 8.5, deficient in nitrogen (300-400 ppm), and low in available phosphorus (2-4 ppm) and low in organic matter 0.05% (Ageeb *et al.*, 1995). The Gezira Scheme lies within the semi dry zone. The annual rainfall is 150 – 300mm. The rainy season is very short. The summer season is characterized by low humidity and high temperatures. April and May are the hottest months. The maximum temperature during summer exceeds 40^0 C. Relative humidity varies markedly during the year from over 65 % in August to around 21 % in March and April. Sun shine in the study area is abundant and more than sufficient for plant growth. The coldest month is January, with mean daily minimum temperature of 21 ^{0}C. There is abundant sunshine and solar energy ranging from 20-26 MJ m^{-2} day^{-1}. The temperature is high and relative humidity is low. The combination of low rainfall, high solar energy and low humidity leads to a high rate of evaporation estimated as 2500 mm annually.

Experimental design and layout:

Acacia ampliceps and *Acacia stenophylla* seedlings were transplanted in June 2002, at 3m in-row spacing and 8.0 m between rows and arranged in an east-west direction. The alley cropping study started in 2006 cropping season. The alleys were divided into three zones: northern, central and southern alley. Weather stations were mounted in each of the three zones of the alleys and in the control plots for monitoring the temperatures and relative humidity. Cup anemometers were positioned in the central part of each alley zone and in the control for measuring wind speed. Portable Light meter as Radiometer was used to measure incoming solar energy in alley cropping and control plots. During seasons 2006, groundnut and maize were grown in the alleys. Each crop was grown separately in randomized complete block design replicated three times.

Sowing method:

Groundnut (variety Medani) was sown on 17^{th} of June 2006 in ridges 80 cm apart and in row spacing of 15 cm. Two seeds per hole were sown at a seed rate of 70.2 kg\ha. Watering was applied at 10- 14 days intervals. Harvesting was at 131 days after sowing. Maize (variety

Mougtama-45) was sown on the 3rd of July 2006. The seeds were sown on ridges 80 cm apart and in row spacing of 25 cm, at rate of 2-3 seeds per hole at a seed rate of 14.8 kg\ ha. The plants were thinned to one plant per hill three weeks after sowing to give standard plant population. Nitrogen fertilization was applied after thinning and before flowering. Harvesting was at 105 days from sowing.

Data collection:

For the woody trees, measurements were done for tree height, diameter at breast height (DBH) and diameter at the base of the trees. Diameters were measured using a caliper. In addition air dry weight for stem wood, branches and twigs and leaves were done. Plant samples were taken at harvest from an area of one square meter in the center of the northern, southern and central alleys and in the control plots to determine plant height (cm), yield and some yield components.

Meteorological data:

Air temperatures: Small weather stations were mounted on iron stands about 2.0 m above ground level. One weather station was placed in each zone of the alley. Maximum temperatures were recorded in a regular systematic way at 08:00 local time every morning.

Air humidity: Wet and dry-bulb thermometers were used for measuring humidity.

Solar radiation: Solar radiation was measured using portable light meter (Radiometer) placed at ground level across the three zones of the alley and the control plot.

Wind speed: Anemometers were located in the central part of the trees' alleys and control plots at 2.0 m above ground.

Measurement of applied irrigation water and soil moisture: Irrigation water was applied to the control and the alleys of *Acacia ampliceps* and *Acacia stenophylla* trees using water meter. Soil moisture was measured using gravimetric sampling method for the depths 0-15, 15-30, 30-45 and 45-60 cm after irrigation and immediately before subsequent irrigation. Three soil samples per plot were taken from each zone of the alley and the control, using auger. Soil samples were dried at 105˚C for 24 hours and soil moisture was calculated on a dry weight bases. The gravimetric percentage (Grav.%) was given by the following equation:

$$\text{Grav.\%} = (\text{Wet soil} - \text{Dry soil}) / \text{Dry soil} \times 100$$

The bulk density (BD) was calculated according to the equations as follow:

$$BD= 0.00003(MC)^{2}-0.0019(MC) +1.274 \text{ .For BD (0-40) \{Eq. 1\}.}$$

$$BD (40-60) = 0.00005(MC)^{2}-0.0019(MC) +1.386 \quad \text{\{Eq. 2\}.}$$

According to these equations the volumetric soil moisture content (VW) was calculated as:

$$\text{Volumetric soil moisture} = \text{Gravimetric} \times \text{BD}$$

The soil water in the profile in (mm) depth = VW × soil depth considered in (mm).

$$\text{Evaportranspiration (ET) per day (mm/d) for the each irrigation interval}$$

$$= \frac{\text{VW}_1 \text{ after irrigation} - \text{VW}_2 \text{ before irrigation}}{\text{Number of days between VW}_1 \; and \; \text{VW}_{21}}$$

Results

Tree performance: Analysis of variance showed that there were highly significant differences (P= 0.001) between tree species in growth and biomass production. Plant height, diameter at breast height DBH, D. base, wood/m^3 and weight of wood and air dry leaves (kg) of *A. ampliceps* and *A. stenophylla* were 8.1 m and 8.9 m, (DBH) of 11.8 and 11.7 cm and diameter at the base (10 cm above the ground) of 15.2 and 16.3 cm, respectively (Table 1).

Microclimatic modification: During 2006 growing season, which extended from June to October, the average values of solar irradiance, maximum temperatures, relative humidity and wind speed were 0. 406 kw/m^{-2}, 37.3 ^{0}C, 66.6 %, and 1.4 m s^{-1}, respectively, and the wind speed was 54 % compared to control. Due to the modifications of microclimate during the growing season, solar irradiance in alley cropping was 60% compared to control (this equals a reduction of 40% in solar irradiance in alley cropping). While the maximum temperatures were reduced by 1.6^0 C, the relative humidity was increased by 19.4% radiation values decreased progressively from June to October. The *A. ampliceps* alley had received higher transmitted radiation (64 % of the control) compared to *A. stenophylla* alley (56 % of the control). On zonal basis, the central alley had the highest transmitted irradiance, while the southern alley had higher transmitted radiation than the northern alley). In general, alley cropping reduced maximum temperatures in different zones of the alleys. The maximum reduction occurred in the southern (-1.96 ^{0}C), while the least reduction occurred in the central alley (-1.2 ^{0}C). On monthly basis, the highest reduction in the maximum temperatures occurred during August and September. Relative humidity was maximum during June and October. The maximum increase occurred in the southern alley (+25.8 %), while the least reduction occurred in the central alley (+16.7%) (Table 2 and 3). In terms of wind speed, the tree hedgerow in the alley experiment reduced wind speed to 54% compared to the control during the growing season of 2006. The highest wind speed (4.06 ms^{-1}) was recorded during July. The maximum wind speed reduction (61%) in the alley cropping experiment occurred during July (Table 4).

Water use consumption differed significantly (P=0.001) between alley cropping and mono-cropping systems and between the different tree species. Alley cropping plots consumed less water (571 m^3) than the control (805 m^3). Saving in irrigation water varied within different tree species and different crops. Water was saved in the *A. stenophyllan* alley by 24 and 24% and in *A. ampliceps*-alley by 34 and 33 % for groundnut and maize, respectively. The maximum saving in irrigation water occurred with *A. ampliceps* (Table 5).

Crops response to microclimatic modifications: Table (6) demonstrate that groundnut pod yield, plant height and weight of 100 seeds in gram were significant differences in alley cropping than in control (P=0.001). The *A. ampliceps* alley produced more yields (14%) than *A. stenophylla* alley (6%). Regarding the zones of the alley, the southern zone gave the highest yields, while the northern zone gave the lowest. Maize yield, plant height, weight of 100 seed/ were significantly (P=0.01) higher in alley cropping than in the control. Correspondingly, *A. ampliceps* alley produced more yields (27%) compared to *A. stenophylla* alley (15 %). In the different zones of *A. ampliceps alley*, the yields increased by 0.1, 48 and 32% for northern, central and southern zones, respectively. While the yield was decreased by (-25%) in the northern zone of *A. stenophylla* alley, it was increased by 51 and 20 % in the central and southern zones, respectively (Table 7).

Discussion

Agroforestry systems have the potential to increase yields by effectively growing two crops at the same time on a single piece of land (Nair, 1991). There are many reasons for combining trees and crops on the same piece of land, such as reducing soil erosion, limited availability of land, modifying the microclimate and improving water use. Huda and Ong (1987) reported that water could be lost through both soil evaporation and percolation to beyond the tree or crop rooting zones it is conceivable that trees could utilize part of the rainfall that would otherwise be lost. When more irrigation water was applied in a drier year, an amount equals to 30-50% of these water requirements was lost through evaporation from standing water/wet surface, which is the main unproductive water (Ibrahim *et al.*, 2002). Agroforestry can provide a reliable tool for soil and water conservation at much lower cost than with traditional techniques such as banks, ditches or terrace (ICRAF, 1993). In this study, the two Australian tree species being used in this trial differed in their ability to extract the water from the different soil horizons as trees differ according to their growth habit and competitive reaction. It has been stated that water could be lost through both soil evaporation and deep percolation beyond the tree or crop rooting zone, it is conceivable that trees could utilize part of the rainfall that would otherwise be lost (Huda and Ong, 1987). In the semi-desert region of the Sudan the main factor determining the success of alley cropping systems is modification of microclimate, which resulted in improving water availability (Shapo and Adam, 2003). The tree canopy reduces and modifies light availability to plants in the understory, with possible beneficial consequences for photosynthesis, water relations and morphogenesis (Bergez *et al.*, 1997). Shapo and Adam (2008) indicated that mostly, the shade length in the alley increased as the solar energy decreased. Besides, the southern shade had always higher length and reached its maximum length at 1600 LT, while the northern shade reached its maximum at 0800 LT. The southern shade, increased gradually from June up to December, and then decreased progressively from January until May. On the other hand, the northern shade increased from January up to June and then decreased from July up to December.

In this study, the trees suffer from water shortage during all seasons except during the rainy season, particularly during summer seasons (March– June) where the irrigation canals were dried for clearance. Analysis of variance showed that A. ampliceps has inferior growth compared to A. stenophylla in terms of plant height, DBH, D.base, etc. The inferiority of growth and shedding of leaves during summer season gave the A. ampliceps the advantage of optimizing radiation for associated crops. The microclimatic elements showed that the micro-environmental variables had a collective effect on growth and yield of groundnut and maize. In the alley cropping plots solar radiation, air temperature and wind speed were reduced, while relative humidity was increased. The ampliceps-alley had received relatively higher incoming radiation (64% of the control) than A. stenophylla (56% of the control). Therefore, the ampliceps-alley had increased groundnut (14%) and maize (27%) yield more than the A. stenophylla alley, which increased the yield of groundnut and maize by 6 and 15%, respectively. These results are supported by Yu *et al.* (1997) who reported that the modification of microclimate favors tea (*Camellia sinensis*) plants growth, improves quality of tea leaves, and increases economic returns per unit land use system.

Furthermore, Vaast *et al.* (2004) reported that tree shade creates more favorable microclimatic conditions for coffee by improving coffee photosynthesis and lowering coffee transpiration in Central America. Although there was difficulty in separating the influence of each climatic factor, nevertheless, the results obtained indicated that the competition for light was the major factor contributing to yield reduction or increase in the alley cropped groundnut and maize. This result was in line with that of Shapo and Adam (2008), who indicated that in northern Sudan, the dense shade in the southern alley caused a relative decrease in winter crop yields; however, the substantial part of increase in yield in the central alley, as a result of optimum solar energy, compensated for this reduction. Consequently, the average yield of wheat, faba bean and common bean was increased in the alleys by 69, 15 and 10%, over control plots, respectively. Through altering micro-environmental elements in alley cropping system in semi-deserts of the Sudan water use is improved by modification in micro-climate of the alley cropping. The highest saving in irrigation water is mainly due to the reduction in solar radiation and wind speed, which are very important factors affecting evapotranspiration and hence water use. (Shapo and Adam, 2008).With respect to water use among the two tree species, the highest saving in irrigation water occurred with A. ampliceps tree. With regard to alley cropping systems, maize gave the highest saving in irrigation water (Table 5). Control plots had consumed much water with maize. Results obtained support the assumption that agroforestry can increase conservation of soil moisture. With respect to zonal alleys; the highest yield of the maize was obtained in the central alley, while the highest yield of groundnut was obtained in the southern alley. The northern alley in all cases had the lowest yield. The yield of groundnut in the southern, central and northern zones of A. ampliceps alley was increased by 25, 15, and 3%, respectively. While the yields decreased by 7% in the northern part of A. stenophylla alley, it increased by 15 and 12% in the southern and central alleys, respectively. This indicates that the groundnut yield did not increase as light supply increased, as other environmental factors, seemed to be influential (e.g. temperatures, humidity and wind speed). In addition, the relatively low increase in yield in the central may be attributed to the fact that the highest radiation in this zone coincided with the least improvement in temperature and humidity. On the other hand, the yield reduction in the northern alley is possibly due to the fact that the lowest radiation in northern alley was concurrent with the complicity of the co-existence of tree-crop roots competition. The yield of maize in the A. ampliceps alley was increased by 0.1, 48 and 32 % in the northern, central and southern zones in the alley. Regarding maize its yields in the southern and central zones of the A. stenophylla alley increased by 20 and 51 %, respectively, while it decreased by 25 % in northern alley.

Conclusions

Agroforestry, which integrates crops and/or livestock with trees and shrubs - has a great potential in the area as it could provide farmers with multiple benefits, including diversified income sources, increased biological production and better water use. The study revealed that the micro-environmental variables were responsible for yield increase or decrease, but in reality, it seemed difficult to separate the complex interacting climatic factors involved in the system. Nevertheless, the obtained results indicated that the most limiting factors that affect the yields of both crops are the water use and irradiance since the differences in maximum temperature, relative humidity and wind speed were negligible within the different zones of the alley. Yield of groundnut and maize in the alley cropping experiment were significantly increased over the control plots. Maize had largely benefited from the microclimatic modification in the alley and in effect gave the highest yields compared to groundnut crops. The higher yields obtained with *A. ampliceps* seemed to be due to its capacity in transmitting sufficient amount of light through its canopy.

Table (1): Biomass production (kg/tree) of Acacia stenophylla and Acacia ampliceps (4 year-old tree)

Tree species	Height (m)	DBH (cm)	D.base (cm)	Wood of stem (kg)/tree	Dry wood of branches and twigs (kg)/tree	Dry leaves (kg)/tree
Acacia stenophylla	8.9	11.7	16.3	20.1	28.3	6.2
Acacia ampliceps	8.1	11.8	15.2	16.4	24.3	7.3
Sig. L	*	-	-	*	* *	*
S.E±	0.08	0.19	0.24	0.5	0.19	0.17
C.V%	1.66	2.48	2.63	4.75	1.23	4.34

Table (2): Average deviation in maximum temperature and relative humidity in the different zones of the alleys of Acacia stenophylla and Acacia ampliceps as related to the control plot (2006)

Direction Months	Southern zone		Northern zone		Central zone		Average in the alley		Control	
	Max	R.H (%)	Max	R.H (%)	Max	R.H (%)	Max	R.H (%)	Max	R.H (%)
June	-1.88	30.0 +	-1.1	32.6+	-1	25 +	-1.32	29 +	40.7	47.0
July	-1.95	29.8 +	-1.56	26.1 +	-1.1	16.2+	-1.54	21.2+	35.9	72.5
August	-2	17.0 +	-1.97	11 +	-1.3	6.8 +	-1.76	8.9 +	34.9	79.6
September	-2	19.4 +	-1.99	12.8 +	-1.5	8 +	-1.84	10.4+	36.2	78.0
October	-1.96	33.0 +	-1.5	28.4 +	-1	27 +	-1.49	27.7+	39	56.0
Mean	**-1.96**	**25.8 +**	**-1.6**	**22.2 +**	**-1.2**	**16.7+**	**-1.6**	**19.4+**	**37.3**	**66.6**

Table (3): Percent irradiance in various zones of the alley of Acacia stenophylla and Acacia ampliceps (as percentage of the control)

Species	*Acacia stenophylla*				*Acacia ampliceps*				Alley cropping (average)	Control
Months	S. Alley	N. Alley	C. Alley	Average	S. Alley	N. Alley	C. Alley	Average		
June	49	44	82	58.3	60	55	89	68	63.2	0.438
July	47	42	80	56.3	57	53	86	65	61	0.417
August	43	41	78	54	53	51	79	61	57.6	0.387
Sep	45	41	78	54.7	55	51	81	62	58.4	0.397
October	44	43	76	53.3	53	51	80	61	58.9	0.390
Mean	**46**	**42**	**79**	**56**	**56**	**52**	**83**	**64**	**60**	**0.406**

S: Southern, N: Northern, C: Central

Table (4): The 24 hours means wind speed in alleys of Acacia stenophylla and Acacia ampliceps and control plots (m/s) season 2006

Month	Alley cropping	Control	Alley cropping/Control
June	2.00	3.96	0.51
July	2.48	4.06	0.61
August	2.05	3.81	0.54
September	1.15	2.12	0.54
October	0.77	1.50	0.51
Average	**1.69**	**3.09**	**0.54**

Table (5): Amount of water applied (m3/ha) in the alley cropping and control (2006)

Species	Mean water applied (m^3)	Water saved as% of control
Acacia ampliceps	532	34
Acacia.stenophylla	610	24
Control	805	
Sig. L	* * *	
S.E±	5.7	
A.ampliceps× Groundnut	528	34
A.ampliceps × Maize	535	33
A.stenophylla× Groundnut	615	24
A.stenophylla × Maize	604	24
Control× Groundnut	806	
Control× Maize	803	
Sig. L	N.s	
S.E±	17.1	
C.V%	**4.6**	

Table (6): Yield and yield components of groundnut in different zones of the alley and control plots

Treatments	Weight of pods (kg/ha)	Yield change as % of control	Plant height (cm)	100-seed weight (g)
A.ampliceps	1773	14	27.5	44.9
A.stenophylla	1651	6	25.2	43.4
Control	1551		22.5	41.9
Sig. L	*		*	N.s
S.E±	43.7		0.68	1.15
North	1514	- 2	25.7	41
Center	1691	9	25.8	45.2
South	1770	14	24	44
Sig. L	* *		*	* *
S.E±	16.1		0.45	0.56
North	1440	- 7	23.9	39.9
Center	1737	12	26.7	43.9
South	1776	15	25	46.2
A. stenophylla	**1651**	**6**	**25.2**	**43.3**
North	1593	3	24.8	42.4
Center	1785	15	28.2	48.8
South	1941	25	29.6	43.6
A. ampliceps	**1773**	**14**	**27.5**	**44.9**
Sig.L	* *		*	*
S.E±	47		0.79	0.98
C.V	**2.9**		**5.4**	**3.9**

Table (7): Yield and yield components of maize in different zones of the alley and control plots

Direction	Seed yield (kg/ha)	Yield as % of control	W/100 seeds (g)	No/of Cobs (m^2)	Plant height(cm)			
					1St	2sd	3rd	4th
A.ampliceps	3662	27	19.3	8	99	131	150	173
A.stenophylla	3326	15	17.1	8	95	118	141	162
Control	2887		14.7	8	88	115	138	158
Sig.L	* *		* *	-	-	*	-	*
S.E±	30.2		0.26	0.17	5.7	2.2	2.9	2.2
North	2633	-9	15.6	8	90	116	138	157
Center	3838	33	18.1	8	101	127	148	173
South	3403	18	17.3	8	91	121	143	164
Sig.L	* *		* *	-	-	* *	* *	* *
S.E±	71.1		0.24	0.16	3.2	1.5	1.4	1.2
Interaction								
North	2890	0.1	17.8	8	85	125	142	158
Center	4273	48	20.2	8	116	139	162	191
South	3823	32	19.8	8	96	128	148	169
A.ampliceps	**3662**	**27**	**19.3**	**8**	**99**	**131**	**150**	**173**
North	2153	-25	15.3	8	93	109	137	156
Center	4353	51	18.5	8	101	127	145	169
South	3470	20	17.4	8	91	118	142	162
A.stenophylla	**3325**	**15**	**17.1**	**8**	**95**	**118**	**141**	**162**
Sig.L	* *		-	-	-	*	*	* *
S.E±	123		0.42	0.28	5.5	2.7	2.1	2
C.V%	**6.48**		**4.25**	**6.25**	**10.1**	**3.8**	**2.88**	**2.1**

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