OPEN ACCESS
Asian Journal of Crop Science
ISSN 1994-7879
DOI: 10.3923/ajcs.2019.25.31

Research Article
Maize Field Biomass Yield and Land Equivalent Ratio under the Influence of Different Management Practices and Location

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Abstract

Background and Objective: The production of maize field biomass and Stover is enhanced by inclusion of legume in cropping system. The objective of the study was to determine the effects of cropping system, nitrogen fertilizer, planting season and location on maize field biomass, Stover yield and land equivalent ratio. **Materials and Methods:** A factorial experiment randomized in complete block design with three replications was conducted during 2011/12 and 2012/13 planting seasons. The experiment comprised of three cropping systems which were cowpea-maize rotation, monocropping maize and intercropped maize. The experiment was conducted at three environmentally different locations (Potchefstroom, Taung and Rustenburg). Two rates of nitrogen fertilizer were applied in kg ha^{-1} at each location (0 and 95 at Potchefstroom, 0 and 92 at Rustenburg, 0 and 113.5 at Taung). Measured parameters were plant population at harvest, field biomass, Stover yield and land equivalent ratio. **Results:** Planting season had significant effect on plant population at harvest, field biomass and Stover yield. Maize harvested during 2012/13 planting season had significantly higher plant population, field biomass and Stover yield than during 2011/12 planting season. The interaction of location×nitrogen fertilizer×plant season had significant effect on plant population at harvest and maize Stover yield. Total LER was found to be higher than 1.0 showing the advantage of intercropping over sole stand. **Conclusion:** Maize field biomass, Stover yield and LER depend on planting season and location.

Key words: Field biomass, land equivalent ratio, nitrogen fertilizer, cropping system, plant population, stover yield

Received: September 05, 2018 Accepted: October 11, 2018 Published: December 15, 2018

Citation: Erick Sebetha, 2019. Maize field biomass yield and land equivalent ratio under the influence of different management practices and location. Asian J. Crop Sci., 11: 25-31.

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize is known to be the feed for livestock as fodder Stover or silage. Maize can be grown to produce forage in winter season to solve problems of livestock feed shortage during this period[1]. Crop rotation and intercropping systems ensure more efficient use of land and greater yield stability[2]. Maize fresh biomass production under intercropping was found to be higher than monocrop maize due to the contribution by legumes in the mixture[3]. Legume contribution to corn in mixture is significant and increase the total biomass yield of mixture[4]. Several studies found that intercropping of soybean with corn resulted an increase in biomass yield[5]. High total biomass yield could be obtained even under no nitrogen fertilization when legume is incorporated in the topsoil[6]. Intercropped corn with legumes is far more effective than monocrop corn to produce higher dry matter yield[3].

Nitrogen fertilizer is accepted as key component to high maize yield and plays a very important role in crop productivity[7]. Biomass yield in maize considerably increases when N was applied up to tassel initiation stage[8]. Application of higher rate of nitrogen per hectare about 50% more than recommended results in maximum biomass yield[9]. Nitrogen fertilizer affects maize dry matter production by influencing leaf area development[10]. Maize Stover was found to increase with increasing N rates in two years study[11].

The comparison between intercrop and sole crop can be made via land equivalent ratio[12]. The LER is defined as the summation of relative yield of sole crop over intercrop components. The partial land equivalent ratio for cowpea decreased in a corn-cowpea intercrop while that of corn increased with an increase in soil nitrogen level. Intercropping system has shown a higher land equivalent ratio (LER) values over sole maize[13]. It was further indicated that, among intercropping treatments, the higher LER was noticed in simultaneous sowing of maize and fodder cowpea. When LER value is equivalent to one, it implies that there is no yield advantage, but when LER is more than one, it means that, there is a yield advantage[14]. Maize field biomass and Stover yield response under rotation, intercropping and monocropping in relation to location and nitrogen fertilizer is not known to most farmers. The information on land equivalent ratio under different environmental conditions in relation to nitrogen fertilization is scanty. The objectives of this study were (i) To determine the effects of location, cropping system and nitrogen fertilization on maize field biomass, Stover yield and (ii) To determine the effects of location, intercropping and nitrogen fertilization on land equivalent ratio (LER).

MATERIALS AND METHODS

Description of study area: The study was conducted at three dryland sites in South Africa, namely the Department of Agriculture Experimental Station in Taung situated at 27°30 S and 24°30 E, Agriculture Research Council-Grain Crops Institute (ARC-GCI) experimental station in Potchefstroom situated at 27°26 S and 27°26 E and the Agricultural Research Council-Institute for Industrial Crops (ARC-IIC) experimental station in Rustenburg 25°43 S and 27°18 E. The ARC-GCI experimental station had clay percentage of 34% and received annual mean rainfall of 622.2 mm, with daily temperature range of 9.1-25.2°C during planting[15]. The ARC-IIC experimental station had clay percentage of 49.5% and received an annual mean rainfall of 661 mm. Taung experimental site is situated in grassland savannah with annual mean rainfall of 1061 mm that begins in October. Potchefstroom (ARC-GCI) has plinthic catena soil, eutrophic, red soil widespread[16]. The soil at Taung is described as Hutton, deep, fine sandy dominated red freely drained, eutrophic with parent material that originated from Aeolian deposits[17]. The soil at Rustenburg (ARC-IIC) has dark, olive grey and clay soil, bristle consistency, medium granular structure[18]. The weather data recorded at three sites during the course of the study was indicated in Table 1 as described by Sebetha and Modi[19].

Experimental design and agronomic practices: The experiment was established in 2010/11 planting season and data considered for experiment was collected during 2011/12 and 2012/13 planting seasons. The experimental design was factorial experiment laid out in Random Complete Block Design (RCBD) with three replicates. The experiment consisted of three cropping systems (monocropping, rotational and intercropping), three locations Potchefstroom, Taung and Rustenburg and two levels of nitrogen fertilizer at each site, which were the amount of 0 and 95; 0 and 92; 0 and 113.5 kg N ha^{-1} applied on maize plots at Potchefstroom, Rustenburg and Taung, respectively. Maize cultivar (PAN 6479) and cowpea (Bechuana white) were used as test crop. The significant of three factor interactions was considered as high factor interactions in this study.

Data collection: Maize field biomass weight was recorded from all plants at harvested area (12 m^2) of each plot and weight at the field by using field scale. Plant population was recorded by counting number of plants per harvested area in each plot.

Stover yield was determined by using the equation as described by Dobermann and Walters[20]:

Table 1: Mean temperature and rainfall data for Potchefstroom, Taung and Rustenburg for the duration of experimental period

Locations	Season	Climate data	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Potch	2011/12	Rainfall (mm)	35.6	66.3	75.9	19.1	33.8	66.3	4.3	0.0
		Max T (°C)	28.6	29.5	28.6	30.4	29.1	28.7	25.0	25.0
		Min T (°C)	11.2	13.8	15.8	16.2	16.3	13.6	8.1	5.2
	2012/13	Rainfall (mm)	21.8	13.5	42.4	45.7	28.7	43.9	47.5	8.1
		Max T (°C)	29.0	30.2	27.9	30.1	31.0	28.4	24.3	22.6
		Min T (°C)	12.4	14.6	15.4	16.8	15.5	14.6	9.1	3.9
Taung	2011/12	Rainfall (mm)	3.1	36.1	71.4	7.9	40.9	12.5	5.1	0.5
		Max T (°C)	31.1	33.3	32.8	36.1	32.9	32.9	28.0	27.7
		Min T (°C)	9.3	10.6	14.8	16.2	17.0	13.8	8.2	4.5
	2012/13	Rainfall (mm)	0.3	8.9	14.9	40.9	32.0	14.2	9.2	8.4
		Max T (°C)	32.5	34.9	32.9	36.3	31.5	31.8	27.3	26.8
		Min T (°C)	10.7	14.3	15.7	17.8	17.7	15.0	9.4	6.2
Rust	2011/12	Rainfall (mm)	23.4	49.8	47.2	19.3	6.4	27.9	6.6	0.3
		Max T (°C)	28.7	30.2	28.3	30.2	30.9	29.0	25.0	25.1
		Min T (°C)	11.7	14.9	17.0	15.3	17.2	14.4	9.3	6.6
	2012/13	Rainfall (mm)	21.1	25.9	48.0	37.3	20.6	10.9	46.5	0.0
		Max T (°C)	28.3	29.9	28.1	29.9	31.1	29.1	25.5	23.2
		Min T (°C)	12.8	14.8	16.1	17.4	16.3	14.7	10.2	4.7

Potch: Potchefstroom, Rust: Rustenburg, Max T (°C): Maximum temperature in degrees celsius, Min T (°C): Minimum temperature in degrees celsius, mm: Millimetres

Table 2: Effects of cropping system, location, nitrogen fertilizer and season on maize plant population (plants ha^{-1}) at harvest area

Cropping system	Intercrop maize	Monocrop maize	Rotation maize
Means	39537.0	43981.5	42731.5
$LSD_{0.05}$	3218.94		
Location	Potchefstroom	Rustenburg	Taung
Means	44629.6	43171.3	38449.1
$LSD_{0.05}$	3218.94		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	38780.9	45385.8	
$LSD_{0.05}$	2628.25		
Planting season	2011/12	2012/13	
Means	39243.8	44922.8	
$LSD_{0.05}$	2628.25		

$$\text{Stover yield} = \frac{\text{Dry sub-sample (kg ha}^{-1})}{\text{Fresh sub-sample (kg ha}^{-1})} \times \text{Field biomass yield (kg ha}^{-1})$$

Land equivalent ratio was determined by using the equation:

$$\text{LER} = \frac{\text{Cowpea intercrop yield}}{\text{Cowpea sole yield}} + \frac{\text{Corn intercrop yield}}{\text{Corn sole crop yield}}$$

When LER$\leq$1, intercropping is disadvantageous while LER$\geq$1, implies intercropping is advantageous[12].

Data analysis: Data were analyzed using analysis of variance (5%) using GenStat 14th edition 2012 and continued by least significant difference (LSD) for a significant different variables that are significant[21]. The type of ANOVA used in this study was three ways.

RESULTS

Effects of treatment factors on maize plant population at harvested area: According to analysis of variance results indicated that cropping system, location, nitrogen fertilizer and planting season were significant ($p<0.05$) on maize plant population at harvested area. The average maize plant population can be seen in Table 2. Based on LSD monocropping maize had significantly higher plant population of 43981.5 plants ha^{-1} than intercropping maize. Maize planted at Potchefstroom and Rustenburg had significantly higher plant population of 44629.6 and 43171.3 plants ha^{-1}, respectively than maize planted at Taung.

Maize without nitrogen fertilizer application had significantly higher plant population of 45385.8 plants ha^{-1} than maize with nitrogen fertilizer. Maize planted during 2012/13 planting season had significantly higher plant population of 44922.8 plants ha^{-1} than maize planted during 2011/12 planting season.

Interaction effects of treatment factors on maize plant population at harvested area: Results of analysis of variance in this study indicated that, interaction of location$\times$nitrogen fertilizer$\times$planting season had significant effect ($p<0.05$) on maize plant population. The interaction of treatment factors on maize plant population can be seen in Table 3. Based on LSD maize planted during 2012/13 planting season at Potchefstroom and Rustenburg under nitrogen fertilization had significantly higher plant population of 51296.3 and

Table 3: Interaction effects of location×nitrogen fertilizer×season on plant population (plants ha^{-1}) at harvest area

	N-fertilizer		Zero-nitrogen	
Locations	2011/12	2012/13	2011/12	2012/13
Potchefstroom	31666.7	51296.3	42592.6	52963.0
Rustenburg	37592.6	46574.1	43240.7	45277.8
Taung	37037.0	28518.5	43333.3	44907.4
$LSD_{0.05}$	6437.88			

Table 4: Effects of cropping system, location, nitrogen fertilizer and planting season on maize field biomass yield in kg ha^{-1}

Cropping system	Intercrop maize	Monocrop maize	Rotation maize
Means	4183.8	5704.0	5241.0
$LSD_{0.05}$	1770.28		
Location	Potchefstroom	Rustenburg	Taung
Means	5591.4	4982.8	4554.6
$LSD_{0.05}$	1770.28		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	5550.7	4535.2	
$LSD_{0.05}$	1445.43		
Planting season	2011/12	2012/13	
Means	3533.7	6552.2	
$LSD_{0.05}$	1445.43		

Table 5: Effects of cropping system, location, nitrogen fertilizer and planting season on maize stover yield (kg ha^{-1})

Cropping system	Intercrop maize	Monocrop maize	Rotation maize
Means	2235.5	2644.3	2919.6
$LSD_{0.05}$	351.83		
Location	Potchefstroom	Rustenburg	Taung
Means	3127.7	2560.2	2111.5
$LSD_{0.05}$	351.83		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	2599.7	2599.9	
$LSD_{0.05}$	287.27		
Planting season	2011/12	2012/13	
Means	2441.6	2758.0	
$LSD_{0.05}$	287.27		

Table 6: Interaction effects of location×nitrogen fertilizer×planting season on maize stover yield (kg ha^{-1})

	N-fertilizer		Zero nitrogen	
Location	2011/12	2012/13	2011/12	2012/13
Potchefstroom	2214.2	4048.6	3231.3	3016.8
Rustenburg	2796.3	2306.2	2486.2	2652.2
Taung	1693.4	2539.3	2228.3	1984.9
$LSD_{0.05}$	703.66			

46574.1 plants ha^{-1}, respectively than maize planted during 2011/12 planting season. Maize planted during 2012/13 planting season at Potchefstroom under zero nitrogen fertilizer had significantly higher plant population of 52963.0 plants ha^{-1} than maize planted during 2011/12 planting season. Maize planted during 2011/12 planting season at Taung under nitrogen fertilizer had significantly higher plant population of 37037.0 plants ha^{-1} than maize planted during 2012/13 planting season.

Effects of treatment factors on maize field biomass yield: Results of analysis of variance in this study indicated that planting season had significant effect ($p<0.05$) on maize field biomass yield. The average maize field biomass yield can be seen on Table 4. Based on LSD maize harvested during 2012/13 planting season had significantly higher field biomass of 6552.2 kg ha^{-1} than maize harvested during 2011/12 planting season.

Effects of treatment factors on maize stover yield: Analysis of variance results indicated that cropping system, location and planting season had significant effect ($p<0.05$) on maize Stover yield. The average maize Stover yield can be seen in Table 5. Based on LSD maize harvested from monocropping and rotational plots had significantly higher Stover yield of 2644.3 and 2919.6 kg ha^{-1}, respectively than maize harvested from intercropping plots. Maize harvested at Potchefstroom had significantly higher Stover yield of 3127.7 kg ha^{-1} than maize harvested at Rustenburg and Taung. Maize harvested at Rustenburg also had significantly higher Stover yield of 2560.2 kg ha^{-1} than maize harvested at Taung. Maize harvested during 2012/13 planting season had significantly higher Stover yield of 2758.0 kg ha^{-1} than maize harvested during 2011/12 planting season.

Interaction effects of treatment factors on maize stover yield: Results of analysis of variance indicated that interaction of location×nitrogen fertilizer×planting season had significant effect ($p<0.05$) on maize Stover yield. The interaction of treatment factors on maize Stover yield can be seen on Table 6. Based on LSD maize harvested during 2012/13 planting season at Potchefstroom and Taung under nitrogen fertilizer had significantly higher Stover yield of 4048.6 and 2539.3 kg ha^{-1}, respectively than during 2011/12 planting season.

Effects of treatment factors on land equivalent ratio (LER): The calculated values of land equivalent ratio (LER) for individual crop as well as total LER under different locations and seasons can be seen in Table 7. At Potchefstroom, the partial LER of maize under maize-cowpea intercropping with nitrogen fertilization was higher during 2012/13 than in 2011/12 planting season. The partial LER of maize under maize-cowpea intercropping with zero-nitrogen fertilizer was higher during 2011/12 than in 2012/13 planting season. The total LER was higher during 2011/12 than in 2012/13 planting season.

Table 7: Partial and total land equivalent ration (LER) as affected by location, planting season and nitrogen fertilization

Locations	Season	Treatments	LER for maize	LER for cowpea	Total LER
Potchefstroom	2011/12	Intercrop/N-fert	0.4	0.7	1.1
		Intercrop/zero-N	0.9	0.7	1.6
	2012/13	Intercrop/N-fert	0.6	0.4	1.0
		Intercrop/zero-N	0.7	0.4	1.1
Taung	2011/12	Intercrop/N-fert	0.7	0.8	1.5
		Intercrop/zero-N	1.8	0.4	2.2
	2012/13	Intercrop/N-fert	0.3	0.6	0.9
		Intercrop/zero-N	1.3	0.9	2.2
Rustenburg	2011/12	Intercrop/N-fert	1.2	0.4	1.6
		Intercrop/zero-N	0.7	0.5	1.2
	2012/13	Intercrop/N-fert	0.9	0.2	1.1
		Intercrop/zero-N	0.5	0.4	0.9

Intercrop/N-fert: Intercropping/nitrogen fertilization, Intercrop/zero-N: Intercropping/zero nitrogen

At Taung, the partial LER of maize under maize-cowpea intercropping with nitrogen fertilization was higher during 2011/12 than in 2012/13 planting season. The partial LER of maize under maize-cowpea intercropping with zero-nitrogen fertilization was also higher during 2011/12 than in 2012/13 planting season. The total LER of maize-cowpea intercropping with nitrogen fertilization was higher during 2011/12 than in 2012/13 planting season.

At Rustenburg, the partial LER of maize under nitrogen and zero nitrogen fertilization was higher during 2011/12 than in 2012/13 planting season. The total LER of maize-cowpea intercropped with nitrogen and zero nitrogen fertilization was higher during 2011/12 than 2012/13 planting season.

DISCUSSION

Cropping systems (monocropping and rotation) were found to be critical factors on high maize plant population and Stover yield in this study. Application of nitrogen fertilizer was found not to have an influence on maize field biomass, Stover yield and land equivalent ratio. The high plant population and Stover yield during harvest under monocropping system might have been attributed to lack of competition for resources. These results corroborated the findings by Mandal *et al*.[22] who reported that sole maize treatment produced significantly higher Stover yield than all other intercropping treatment. The higher plant population and Stover yield in this study contradicted the findings by Agyare *et al*.[2] who reported maize yield to be better in rotation than intercropping and monocropping. Higher Stover yield under rotation system might have been attributed to improved soil fertility status. This agreed with similar findings by Stanger and Lauer[23] who reported that legume-corn rotation was beneficial in maintaining corn yield. The high plant population and Stover yield during harvest at Potchefstroom and Rustenburg might have been attributed to soil structure in both locations, which have normal clay percentage to hold water and nutrients. This correlates with similar findings by Oyinlola and Jinadu[24] who reported that, clay soil retain water and nutrients. The higher plant population and Stover yield at Potchefstroom and Rustenburg might have been attributed also to low salinity level at both location. This agreed with similar findings by Brugnoli and Lauteri[25] who observed the higher dry yield on the low salinity level in the corn-cowpea intercrop. The higher maize plant population, field biomass and Stover yield during harvest might have been attributed to rainfall availability during growth and reproductive stages (January to April) as indicated in Table 1, which resulted in high maize production.

The partial LER for maize in both planting seasons at three sites was higher as compared to cowpea and this agrees with similar findings by Yilmaz *et al*.[26] who reported that partial LER of cowpea decreased as the proportion of maize increased in mix-proportions. The partial LER for cowpea at Taung was higher showing the advantageous of cowpea and this agreed with findings by Yilmaz *et al*.[26] who reported that cowpea appeared to have more beneficial land use efficiency in all mixture. In this study, the total LER were found to be higher than one showing the advantage of intercropping over sole stands in regards to the use of environmental sources for plant growth[27]. The total LER of 2.2 at Taung during 2011/12 and 2012/13 planting seasons under intercropping with zero nitrogen corroborate the findings by Bilalis *et al*.[28] who observed the higher LER values in corn-cowpea system than in the corn-bean system. The findings of this study were significant since application of nitrogen fertilizer has no influence on the improvement of total LER. The higher total LER at Taung was not expected since the site had high sand percentage.

CONCLUSION

The results of the study indicated that Potchefstroom and Rustenburg were good locations for maize production. Planting season played a role on production of maize where 2012/13 planting season resulted in higher field biomass and stover yield. Total LER was found to be higher than 1.0 showing the advantage of intercropping over sole stand. Nitrogen fertilizer application in this study did not affect production of maize in terms of plant population, field biomass and Stover yield. Application of nitrogen fertilizer had no influence on the improvement of total LER in this study.

SIGNIFICANCE STATEMENT

This study discovered that the cropping systems with high production of maize in terms of plant population and Stover yield were monocropping and rotational systems. Production of maize differed across the locations due to different soil types and climatic conditions. In this study, it was discovered that Potchefstroom and Rustenburg were good production areas for maize. It was also discovered that the application of nitrogen fertilizer did not influence the land equivalent ratio.

ACKNOWLEDGMENTS

The authors would like to thank the ARC-GCI and University of KwaZulu-Natal for allowing the study to take place. The study was funded by Agricultural Research Council (ARC) and National Research Foundation (NRF) under the financial grand number PDP 9. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

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