Research Article Open Access

# Effect of Facilitative Interaction of Sorghum-Cowpea Intercrop on Sorghum Growth Rate and Yields

Andrew Ogolla Egesa[1,*], Steven Njeru Njagi[2], Catherine Wanjiku Muui[1]

[1]Department of Agricultural Science and Technology, Kenyatta University, Nairobi, 43844-00100, Kenya
[2]Ministry of Agriculture, Embu County, 81-60103, Embu, Kenya

**Article History**
**Received**
March 15, 2016

**Published Online**
November 30, 2016

**Keywords:**
Climate change
High Yields
Intercropping,
Low inputs,
Sorghum,
Yield security

**Abstract:** Change in temperature and rainfall patterns has resulted in lower midlands of Kenya to become hotter and drier, resulting in lower sorghum yields in these marginal areas. A field experiment was conducted in Eastern Kenya using cowpea-sorghum intercropping to compensate lower sorghum yields. Random complete block design (RCBD) was adopted with four intercropping patterns (treatments) replicated four times. The different intercropping patterns, included: sole sorghum [1(0), control], sorghum-cowpea intercropping [1(1)], sorghum-cowpea-lines ratio [2(3)], mixed sorghum-cowpea sowing. Plant height, number of leaves and leaf broadness were recorded at every 13 days, initiated 7 days after emergence. The total grain yield was measured at harvesting. Data collected was subjected to analysis of variance (ANOVA) using scientific analysis software (SAS, 9.1), and means separated at Fishers 0.05 LSD. Sorghum in pattern 1, produced broader leaves and higher yield of sorghum grains, (2.9 t ha$^{-1}$). Pattern 2 (2.5 t ha$^{-1}$), and 3 (2.3 t ha$^{-1}$), resulted in relatively lower yields. The sole crop-sorghum [1(0)] was the poorest at 1.8 t ha$^{-1}$, yielding below the cultivar potential of 2t ha$^{-1}$. Sorghum-cowpea uniform intercropping [1(1)] resulted in higher sorghum yield potentially due to fertility advantage of legume crop. This results indicate the importance of using suitable intercropping patterns for realization of intercropping benefits in areas with low soil fertility and erratic rainfall.

***Corresponding author:** Andrew Ogolla Egesa, ayechoogola@gmail.com

**Cite this article as:** Egesa, A.O., S.N. Njagi and C.W. Muui. 2016. **Effect of facilitative interaction of sorghum-cowpea intercrop on sorghum growth rate and yields.** Journal of Environmental & Agricultural Sciences. 9: 50-58.

## 1. Introduction

Irrigation and application of fertilizers in modern agriculture has been set up to solve problems of increased incidences of erratic rains and poor soil fertility in the tropics. These new found technologies are still far-fetched for subsistence and small-scale farmers of Eastern Kenya especially in Embu County. In order to achieve millennium development goal of food security, area under crop production need to be expanded and vast dry lands including the marginal areas in Kenya utilized for food production, this has been exhibited by increased advocacy for use of hardy crops, (Poulton and Kanyinga. 2014). Sorghum, one of the hardy crops adapted to dry conditions, despite it being embraced in these dry lands, the yields obtained have been continually poor, (Rao et al., 2015). This has been as a result of unpredictable rainfall patterns causing high levels of water deficit to the plant at critical stages of crop development, increased temperatures and high levels of soil infertility.

Evaluations of climate resilient conservation planting systems of which one is intercropping offers options for betterment of the situation of poor performance of crops (Malézieux et al., 2009; Lithourgidis et al., 2011; Otim et al., 2015; Brooker et al., 2016; Himanen et al., 2016). In order to meet future food demand and increase resource use efficiencies, sustainable intensification is required in agricultural crops (Mao et al., 2012; Yu et al., 2015; Bai et al., 2016).

In this case a legume cowpea (*Vigna unguiculata L*) came in handy as it is adapted to dry tropical conditions (Varshney et al., 2009; Kumar et al., 2011). In studies of ecology of intercropping, it had been indicated that numerous indirect and direct advantages of intercropped systems including increased overall productivity, ecological services and economic profitability are common (Singh et al., 2003; Malezeux et al., 2009; Lithourgidis et al., 2011). In that case when sorghum is intercropped with cowpea, there would be benefits of increased nitrogen (N) utilization (through 'N' fixation), and because of this, that critical resource would be utilized by the legume in $N_2$ forms and by the Non-legume in $NO_3$ forms, the excess N due to fixation will increase the supply to neighbouring plants of other species

(Graham and Vance, 2003; Bedoussac and Justes, 2010; Cong et al., 2015). In addition to N fixation, intercropped legumes also increase availability of other nutrients including phosphorous (P) (Hinsinger et al., 2011; Isaac et al., 2012; Betencourt et al., 2012; Kolawole, 2012; Xia et al., 2013; Crème et al., 2016), prevent nutrient losses (Cavagnaro et al., 2015) and also help in Phytoremediation of heavy metal (Chen et al., 2015). Therefore incorporation of legumes as intercrop also increase microbial population in the soil and their services (Wahbi et al., 2016).

Presence of rhizosphere microflora and mycorrhiza on one species in intercropped systems lead to mobilization and greater availability of nutrients (Monti et al., 2016) and not only to species concerned but also to the associated species (Graham and Vance, 2003; Araújo et al., 2015; Doring, 2015; Brooker et al., 2016; Weisany et al., 2016a; Weisany et al., 2016b). Weed suppression rate is usually stronger in intercropping than in the monoculture situation (Chou, 199; Hauggaard-Nielsen et al., 2001; Singh et al., 2003), same to decreased rates of serious pest, (Ampong-Nyarko et al., 1994; Sanginga et al, 2003; Boudreau, 2013; Lopez et al., 2016) and disease (Trenbath, 1993; Boudreau, 2013; Brooker et al., 2016) incidences in intercrops. All the above complex interactions are likely to enhance productivity of intercrops if the cropping patterns and the planting density were in their right proportions (Hauggaard-Nielsen et al., 2016; Hu et al., 2016; Huang et al., 2017).

Li et al., (2016), when discussing rhizosphere alteration by legumes, argued that cereals lacking strong rhizosphere acidification capacity, when intercropped with legumes could benefit from nutrients solubilized by the legume root exudates. Colonization of cowpea roots with arbuscular mycorrhiza, similar to the cases with many mycorrhizal plants has been credited to improved P availability and use efficiency in such plants, improving their growth under limited P conditions, these improvement also occurs in mycorrhizal plants intercropped with non mycorrihizal ones (Ning and Cumming, 2001; Taffouo et al., 2014). Increased availability of P, K, Ca and Mg in intercropping than in pure stands, for component crops grown in same conditions but separately, has always been attributed to collective resourcing of nutrients by their roots and through the underground interlinks, as a result, excess forms of a given nutrient are known to be used by the other crop, especially where nutrient requirements and use by the intercropped plants are different.

In sorghum-cowpea intercropping, competition for space results in increased soil cover and reduced soil erosion (Morel et al., 2012). Studies by Zougmore et al., (2000), in West Africa showed reduced run off as an effect of sorghum-cowpea intercropping. In pest control, the disruptive crop effect especially to mono-phagous pests, this together with mixed chemical cues released by plants in polycultures creates unsuitable environment resulting in a reduction of pest activity, such cooperation has been observed to be very wide with experiments carried out from 1983 to 1985 at Mbita research station (ICIPE) in the periods of shoot fly (*Atherigonas occata rond*), stem borers and *Sesmia calamistis* indicating legumes contribution to reduction in these pests in sorghum – legume intercrops.

Generally, there have been increasing interests in conservation agriculture with agro forestry scientists stating that it would assist to rebuild soil health and enhance sustainability of resource poor agricultural systems of developing world. Mousavi and Eskandari, (2011), had singled out intercropping as very important, among the sustainable and environmental friendly agricultural systems, due to its promotion of plant diversity. Similarly, alternative N sources for plant growth have been encouraged for reduced environmental pollution, and according to Garg and Geetanjali, (2007), this could be generated by the legumes-that serve as candidates for intercropping systems. This study had its main interest in evaluations of sorghum-cowpea intercropping patterns, to understand the likelihood of presence of an influence in sorghum growth and yields in poor soils and where rainfall was insufficient and unpredictable.

## 2. Materials and Methods

The field experiment was carried out at Kanyuambora - Mbeere North in Embu County (Kenya) during the rainy season of March-July, 2015. This site is approximately located at 0.335’S, 37.37’E and 900m above sea level in the zone 3 (medium potential) of ecological zones of Kenya. Average Rainfall received is about 640 to 1100 mm per annum, temperatures, range from 24 to 32 $^{o}$C and the soils are ferrasols – sandy reddish brown, with low fertility levels. Sorghum variety- Gadam and cowpea variety-Katumani (K80), all from Kenya Agricultural and Livestock Research Organization (KALRO) - Embu were used.

**Table 1. Sorghum plant height (cm) under different intercropping patterns of sorghum cowpea**

| Treatments | 13 DAE | 26 DAE | 39 DAE | 52 DAE | 65 DAE |
|---|---|---|---|---|---|
| **1(0) Sorghum (Monocrop)** | 9.55a | 36.43a | 70.08a | 130.15a | 135.05a |
| **1(1) Intercropping** | 10.58a | 39.98a | 70.50a | 133.73a | 140.10a |
| **2(3) Intercropping** | 10.78a | 41.38a | 70.55a | 133.00a | 138.68a |
| **Mix cropping** | 9.28a | 35.05a | 67.30a | 128.83a | 130.10a |
| ***P* value** | 0.1070 | 0.1313 | 0.8959 | 0.7582 | 0.0561 |

*Means of with the same letters within a column are not significantly different. DAE, days after emergence; 1(0), sole sorghum (monocropping; 1(1), One linesorghum with one line cowpea; 2(3), two lines sorghum with three lines of cowpea; mix cropping, sorghum-cowpea sown in the same line.

Four planting patterns (treatments) were adopted as follows; sorghum sole crop as control 1(0) (Sorghum monocrop); one sorghum to one cowpea line i.e., 1(1), two sorghum to three cowpea lines i.e., 2(3), sorghum-cowpea in the same line (mix cropping). The spacing between rows and plants were maintained 75 cm × 20 cm for sorghum and 20 cm × 15 cm for cowpea (Mburu, 2002). Sowing was done with uniform plant density i.e., two plants of sorghum and cowpea per hole, as per described in the treatment. Two weeks after emergence, thinning was carried out to reduce the sorghum population to an average of ~60 plants per plot.

Compound fertilizer 23:23:00 (N:P$_2$O$_5$:K$_2$O) at a rate of 87 kg/ha$^{-1}$ was used. In each hole, an amount of 6.5 g of the fertilizer was placed (Mburu, 2002). Top dressing was not carried out since beneficial effect of N fixation and combined nutrient resourcing were presumed to have occurred. Weed control was done at three weeks and at one and a half months after emergence. Third and fourth weeding were not carried out, since the effect of cowpea canopies would have enhanced weed suppression. Scouting for pest and diseases was carried out regularly for prompt control measures. A few symptoms and signs of aphid and stem borers were observed but these were way below economic threshold levels to warrant establishment of control measures on growth; plant height, length of the 3rd leaf from the funnel, width of the 3rd leaf from the funnel taken at the middle and number of leaves were recorded after every 13 days as measures of growth rate. Panicle sizes were recorded and yield measured by weighing of the dry grains at critical moisture level.

The data collected on all parameters was subjected to analysis of variance using SAS (Version 9.1) and significant difference of means separated at Fishers 0.05 LSD.

## 3. Results and Discussion

### 3.1 Sorghum growth rate

Generally the variations in the maximum mean height attained by sorghum plants across the treatments was insignificant throughout the growth period, (Table 1). The number of leaves on sorghum plant was significantly varied 26 days after emergence (DAE), Intercropping with higher ratio of cowpea [2(3)] produced the highest number of leaves, which was statistically at par with sorghum-cowpea mix cropping and the sole crop sorghum [1(0)]. Intercropping with equal ration i.e, one sorghum to one cowpea line pattern [1(1)], had significantly low number of leaves, in comparison to all the other 3 intercropping patterns [1(0), 2(3) and mix cropping], (Table 2), this could have been an indicator of elevated interspecies competition for growth resources or reluctant phenological advancement of the crop. The later is believed to be a benefit of unstrained resource supply to the plant. Cowpea, when intercropped with sorghum enhances the growth rate of sorghum by adding in the soil through biological N fixation (Stern, 1993; Morel et al., 2012).

**Table 2. Sorghum number of leaves under different intercropping patterns of sorghum cowpea**

| Treatments | 13 DAE | 26 DAE | 39 DAE | 52 DAE | 65 DAE |
|---|---|---|---|---|---|
| **1(0) Sorghum (Monocrop)** | 3.4a | 6.1ab | 9.0a | 9.1a | 8.6a |
| **1(1) Intercropping** | 4.5a | 5.4b | 8.4a | 8.8a | 8.5a |
| **2(3) Intercropping** | 3.6a | 6.2a | 8.7a | 9.1a | 8.3a |
| **Mix cropping** | 3.3a | 6.0ab | 8.0a | 8.9a | 8.0a |
| ***P* value** | 0.0892 | 0.0350 | 0.1370 | 0.08815 | 0.6070 |

*Means of with the same letters within a column are not significantly different. . DAE, days after emergence; 1(0), sole sorghum (monocropping; 1(1), One linesorghum with one line cowpea; 2(3), two lines sorghum with three lines of cowpea; mix cropping, sorghum-cowpea sown in the same line.

**Table 3. Leaf broadness of Sorghum under different intercropping patterns of sorghum cowpea**

| Treatments | 13 DAE | 26 DAE | 39 DAE | 52 DAE | 65 DAE |
|---|---|---|---|---|---|
| **1(0) Sorghum (Monocrop)** | 1.60a | 4.95a | 5.85ab | 6.08ab | 5.88ab |
| **1(1) Intercropping** | 1.65a | 4.58a | 6.50a | 6.95a | 6.68a |
| **2(3) Intercropping** | 1.58a | 4.80a | 5.30ab | 5.75ab | 5.40ab |
| **Mix cropping** | 1.75a | 3.784a | 4.83b | 5.28b | 5.00b |
| ***P* value** | 0.9011 | 0.0858 | 0.0485 | 0.0226 | 0.0323 |

*Means of with the same letters within a column are not significantly different. . DAE, days after emergence; 1(0), sole sorghum (monocropping; 1(1), One linesorghum with one line cowpea; 2(3), two lines sorghum with three lines of cowpea; mix cropping, sorghum-cowpea sown in the same line.

Variations in sorghum growth observed could have been conferred by improved P and N supply to the plant. Maintaining a rapid shoot development with relaxed leaf set is an indicator of luxurious growth. At four weeks, the cowpeas had relatively broad leaves this enabled moisture conservation and enhanced N fixation through nodulation. Benefits of N fixation have been credited for enhanced sorghum growth under intercropping systems by Mohammed et al., (2008). Sole sorghum planatation [1(0)] is likely to have been adversely affected with poor resource utilization efficiency (Owuor, 2005; Awal et al., 2006; Bedoussac and Justes, 2010; Chimonyo et al., 2016; Xue et al., 2016).

At 13 DAE, the width of the third leaf from the funnel did not vary significantly across the intercropped patterns, (Table 3). At 26 DAE, the case was similar, with all the treatments having little variation. However, at 39 DAE, significant variations in leaf broadness across the treatments were observed, intercropping pattern of one sorghum to one cowpea line [1(1)] had broader leaves, this was an indicator of increased assimilate accumulation which would later translate to good yields. Similarly these leaves had a high radiation use efficiency as a benefit of the large photosynthetic area.

Results of enhanced growth performance of intercrops had been previously attributed to a role of the intercropped state, and the effects credited to the optimal moisture conservation and N fixation benefit in the intercropped field (Mucheru et al., 2009). It is similarly important to note that in the 3 intercropped patterns, penetration of the excess solar radiation was known to have been relatively low because of additional shade (ground cover). A higher ground cover such that the sun rays penetrate less to the ground is likely to be important. The cowpeas in equal ratio of intercropping [1(1)] were vigorous, developing a dense second canopy cover shading much of the spaces in between sorghum lines, this wasn't the case to the other three patterns [1(0), 2(3) and mix cropping]. The secondary canopy cover by cowpeas is believed to have conferred better moisture conservation to cereals as described by Morel et al., (2012).

### 3.2 Yields and yield component

In yields, intercropping pattern with equal rows of both crops [1(1)], was the best performed in comparison to all the other three patterns [1(0), 2(3) and mix cropping]. This pattern can be visualized as having been able to attain about more than 60% yield increase above the sole crop sorghum, higher yields of sorghum in sorghum-cowpea research activities had been previsouly reported by Richards, (2000) and Musa, (2012). Similarly, sorghum-cowpea intercropping pattern with equal rows of both crops [1(1)], exhibited the best performance in both having large panicles and high total grain yield per panicle, (Table 4 and Table 5). Good growth of the sorghum crop is likely to be a factor that resulted in higher yields. Generally intercrop performance showed increasing trend from sorghum-cowpea mix cropping, and 2(3) intercropping and reached maximum at 1(1) intercropping (Table 5).

**Table 4. Sorghum panicle size under different sorghum-cowpea intercropping patterns**

| Treatments | Panicle Length(cm) | Panicle Width (cm) |
|---|---|---|
| **1(0) Sorghum (Monocrop)** | 14.56c | 3.42c |
| **1(1) Intercropping** | 19.35a | 4.73a |
| **2(3) Intercropping** | 17.71b | 4.15b |
| **Mix cropping** | 17.58b | 3.92b |
| ***P* value** | 0.0001 | 0.0001 |

*Means of with the same letters within a column are not significantly different. 1(0), sole sorghum (monocropping; 1(1), One linesorghum with one line cowpea; 2(3), two lines sorghum with three lines of cowpea; mix cropping, sorghum-cowpea sown in the same line.

**Table 5. Sorghum yield under different intercropping patterns of sorghum cowpea**

| Treatments | Sorghum Plant Population | Cowpea yield plot$^{-1}$ (g) | Sorghum Yield | | | |
|---|---|---|---|---|---|---|
| | | | Panicle$^{-1}$ (g) | Plot$^{-1}$ (g) | Anomaly plot$^{-1}$ (g) | Anomaly (%) |
| **1(0) Sorghum** | 56 | - | 25.18c | 1410.08 | _ | 100.00% |
| **1(1) Intercropping** | 55 | 340.84 | 42.51a | 2338.05 | +927.97 | +65.81% |
| **2(3) Intercropping** | 53 | 651.95 | 38.03b | 2015.59 | +605.51 | +42.94% |
| **Mix cropping** | 53 | 171.65 | 34.25b | 1815.25 | +405.17 | +28.73% |
| ***P* value** | | | 0.0001 | | | |

*Means of with the same letters within a column are not significantly different. 1(0), sole sorghum (monocropping; 1(1), One linesorghum with one line cowpea; 2(3), two lines sorghum with three lines of cowpea; mix cropping, sorghum-cowpea sown in the same line.

The sole crop sorghum [1(0)] was the least performed in growth especially in case of plant height and the final yields (Table 1 and Table 5). Reflecting back on the growth for these varying intercrop patterns, as in Table 2; leaf broadness is seen as the top most factor leading to the higher yields; enhanced photosynthesis of broader leaves was described as a factor conferring potential for high yields by Cousins, (2003). Other leaf based factors belived to have enhanced efficient capture of solar radiations, include a high leaf area index, which is believed to highly benefit the plant by resulting into increased photosynthesis as reported by Ceotto et al., (2013) who attributed high canopy cover to interception of photosynthetically active radiations.

Although sorghum has the $C_4$ photosynthetic pathway, the lower younger leaves at seedlings stage do exhibit $C_3$ like photosynthesis, which is similarly low efficient same to reduced photosynthesis for mature lower sorghum leaves affected by shading effect, with this regard this research had a specific bias to the 3rd leaf from the funnel (Table.2), basically because, at all the stages of sorghum development this leaf would always be fully expanded and at most, be exposed to more intense solar radiation, and hence it is with that fact that it is presumed to exhibit more of the $C_4$ photosynthesis, this was likely to be the case being that, this activity was done at Mbeere north one of the dry sunny parts of lower eastern Kenya. Many studies have clearly elucidated that leaves are the food assimilates powerhouses where minerals are turned into nutrients; this clearly expounds the benefit of having broad leaves in sorghum plant as seen in one sorghum to one cowpea intercropping pattern (Duli, 2004).

Mwangi, (2013), attributed development of extremely narrow leaves in sorghum as an effect of soil N deficiencies, this is likely to have been the cause of the narrow leaves in sole crop sorghum and Sorghum cowpea in the same line. One sorghum to one cowpea line having broad leaves points out to the enhanced supply of N for that intercropped pattern (Table 2). Broad leaves have high absorbing rate for solar radiation, this could have resulted into supper manufacture of assimilates through the vital process of photosynthesis (Midmore, 1993; Mao et al., 2012). Better assimilate accumulation in the leaves at late vegetative stage has been clearly presumed to cause an influence in the resultant high grain weight, as described by Nguyen and Blum, (2004). This cannot be better explained when the concept of N fixation benefits to the cereal crop by the legume are left out, primarily considering the specific requirements and conditions for the process. In view of the similarity in the three varied sorghum intercropped patterns, all having cowpea inclusion, except the sole crop, begs the question why varied results? From this point we note that sorghum and cowpeas are all crops adapted to dry lands as illustrated by Shuaibu, (2015), they have ability to utilize little moisture and nutrients for their growth and development. The two crops exhibit varied mechanisms, in which the Gadam sorghum showing the stay green characteristic, while cowpea showing faster uptake of water and slower utilization (Ren et al., 2016). Therefore in case of sole crop sorghum, the reduced crop height, and small panicle sizes could have been as a result of remobilization of assimilates in production of sorbital compounds that could have enhanced increased osmotic potential of the sorghum plant for water absorption in the dry soil and or, retained plant tissue integrity in low water levels. This sole crop sorghum provided low soil cover. The poor canopy formed by the erect sorghum leaves, resulting in less interception of solar radiation (Awal et al., 2006) and rapid evaporation of water from the soil is very common to sorghum monocrops (Bidlake, 2000). Considering poor soil fertility, in all the major nutrients, the low supply of these vital resources also contributed to the poor growth of the sorghum as a result the sole crop sorghum ended up with poor yields, (Table 5).

In sorghum-cowpea mix cropping, though the sorghum plants were intercropped with the cowpea, hence had a possblility of benefiting from potential N fixation, enhanced nutrient resourcing by the increased rhizobium coverage, water conservation by the increased canopy, pest reduction by the repellent effect and reduced weed development (Doring, 2015). The performance of this treatment was fair and not good, the most probable explanation is that, two dry land adapted plants were grown in the same line, this increased competition for water, similarly there was a large space between rows uncovered. When the plants were about 6 weeks old, reduced rainfall and increased solar radiation resulted in super rapid loss of water from the exposed soil surface this impacted negatively on the formation of root nodules later on in cowpeas, as the process is highly dependent on water, this is the case to most legumes. Reduced activity of nitrogenase due to limited water in *Phaseolus vulgaris L* had similarly been observed by Ramos et al., (2003). Related to nitrogrn fixation, there was a likelihood of water deficit condition resulting in faster death of mycorrhiza in the earlier stages of the plant growth, a case described by Naim, (2013).

Two planting patterns of one sorghum to one cowpea line and two sorghum to three cowpea lines respectively performed well, this could have been due to good root nodulation of cowpea (Oseni, 2010; Morel et al., 2012), water conservation by the enhanced canopy cover, and improved mineral resourcing by the colonization of the roots of the plants by mycorrhiza, reduced weed development and the pest repellent effect by the cowpea (Shuaibu, 2015). All the same, it could have been that the N fixation benefit was not much at two sorghum to three cowpea lines because, the sorghum-legume roots were a bit far apart and some larger surface between two sorghum plant lines was left exposed to water loss by evaporation. Equal ratio of sorghum-cowpea intercropping [1(1)], enabled individual intercropped plant roots interaction (Oseni, 2010), this could have been the betterment of mineral resourcing, uptake and use of N and other nutrients from the disintegrating root nodules and mycorrhiza at and near the roots of sorghum plants, resulting in yields of 2.9 tons per ha, this was the highest yield attained. Musa, (2012), was able to clearly elucidate the effect of nodulation as a major factor that contributes to increase in mineral composition of sorghum grains obtained in addition to high grain weight. The yields of cowpeas of > 2kg in an area of 32m$^2$ for pattern one is sufficient for use as inputs for subsequent sorghum production. Experimentation and use of other legumes in sorghum intercropping patterns has potential of better yields under low moisture and low soil N.

## 4. Conclusion

Intercropping sorghum and cowpea with low fertilizer inputs under low rainfall conditions at lower Embu in Eastern Kenya resulted in higher yields of Gadam sorghum at intercropping pattern one sorghum to one cowpea line i.e., 1(1). Two sorghum to three cowpea lines i.e., 2(3), sorghum-cowpea in the same line and the sole crop sorghum resulted in relatively lower yields. Increased sorghum yields, especially where water and fertilizer inputs are insufficient can be obtained through legume intercropping; this is when done according to the recommended planting patterns and plant densities for the region. During provision of extension services at Kenyan dry lands especially for the dry lands where sorghum is grown; the available recommended intercropping patterns should be demonstrated to farmers. Researchers should also carry out more study on different sorghum legume intercropping systems. The role of nitrogen and varied water regimes on sorghum crop growth should also be extensively evaluated.

**Acknowledgement:** The authors are thankful for the logistics support from Kenyatta University and the farmer at Mbeere who donated the piece of land for supporting the research.

**Competing Interests:** The authors declare that there is no potential conflict of interest.

## References

Ampong-Nyarko, K., K.V.S. Reddy, R.A. Nyang'or and K.N. Saxena. 1994. Reduction of insect pest attack on sorghum and cowpea by intercropping. Entomologia Experimentalis et Applicata. 70(2): 179-184.

Araújo, S.S., S. Beebe, M. Crespi, B. Delbreil, E. M. González, V. Gruber, I. Lejeune-Henaut, W. Link, M.J. Monteros, E. Prats, I. Rao, V. Vadez and M.C.V. Patto. 2015. Abiotic stress responses in legumes: Strategies used to cope with environmental challenges. Crit. Rev. Plant Sci. 34:237-280.

Awal, M.A., H. Koshi and T. Ikeda. 2006. Radiation interception and use by maize/peanut intercrop canopy. Agric. Forest Meteorol. 139(1–2): 74-83.

Bai, W., Z. Sun, J. Zheng, G. Du, L. Feng, Q. Cai, N. Yang, C. Feng, Z. Zhang, J.B. Evers, W. van der Werf, and L. Zhang. 2016. Mixing trees and crops increases land and water use efficiencies in a semi-arid area. Agric. Water Manag. 178: 281-290.

Bedoussac, L. and E. Justes. 2010. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant Soil. 330(1): 19-35.

Betencourt, E., M. Duputel, B. Colomb, D. Desclaux and P. Hinsinger. 2012. Intercropping promotes the ability of durum wheat and chickpea to increase rhizosphere phosphorus availability in a low P soil. Soil Biol. Biochem. 46: 181-190.

Bidlake, W.R. 2000. Evapotranspiration from selected fallowed agricultural fields on the Tule lake national wildlife refuge, california, during May to October 2000. U.S. Geological Survey-Water-Resources Investigations Report 02-4055. Washington.2002.

Boudreau, M.A. 2013. Diseases in intercropping systems. Ann. Rev. Phytopathol. 51: 499–519.

Brooker, R.W., A.J. Karley, A.C. Newton, R.J. Pakeman, C. Schöb. 2016. Facilitation and sustainable agriculture: a mechanistic approach to reconciling crop production and conservation. Funct. Ecol. 30(1): 98-107.

Cavagnaro, T.R., S.F. Bender, H.R. Asghari and M.G.A.v.d. Heijden. 2015. The role of arbuscular mycorrhizas in reducing soil nutrient loss. Trends Plant Sci. 20(5): 283-290.

Ceotto, E., M.D. Candilo, F. Cartelli, F.W. Badeck, F. Rizza, C. Soave, A. Volta, G. Villani and V. Marletto. 2013. Comparing solar radiation interception and use efficiency for the energy crops giant reed (*Arundo donax*) and sweet sorghum (*Sorghum bicolor L*. Moench.). Field Crops Res. 149: 159–166

Chen, B., X. Ma, G. Liu, X. Xu, F. Pan, J. Zhang, S. Tian, Y. Feng and X. Yang. 2015. An endophytic bacterium Acinetobacter calcoaceticus Sasm3-enhanced phytoremediation of nitrate–cadmium compound polluted soil by intercropping Sedum alfredii with oilseed rape. Environ. Sci. Poll. Res. 22(22): 17625-17635.

Chimonyo, V.G.P., A.T. Modi and T. Mabhaudhi. 2016. Simulating yield and water use of a sorghum–cowpea intercrop using APSIM. Agric. Water Manag. 177: 317-328.

Chou, C.-H. 1999. Roles of allelopathy in plant biodiversity and sustainable agriculture. Crit. Rev. Plant Sci. 18(5): 609-636.

Cong, W.-F., E. Hoffland, L. Li, J. Six, J.-H. Sun, X.-G. Bao, F.-S. Zhang and W. Van Der Werf. 2015. Intercropping enhances soil carbon and nitrogen. Global Change Biol. 21(4): 1715-1726.

Cousins, A.B., N.R. Adam, G.W. Wall, P.J. Pinter, M.J. Ottman, S.W. Leavitt and A.N. Webber. 2003. Development of C4 photosynthesis in sorghum leaves grown under free air $CO^2$ enrichment. J. Exp. Bot. 54(389): 1969-1975.

Crème, A., C. Rumpel, F. Gastal, M. de la Luz Mora Gil and A. Chabbi. 2016. Effects of grasses and a legume grown in monoculture or mixture on soil organic matter and phosphorus forms. Plant Soil. 402(1): 117-128.

Döring, T.F. 2015. Grain Legume Cropping Systems in Temperate Climates. In: De Ron, A.M. (Ed.), Grain Legumes. Springer New York, pp. 401-434.

Garg, N. and Geetanjali. 2007. Symbiotic nitrogen fixation in legume nodules: process and signaling. A review. Agron Sustain. Dev. 27: 59–68.

Graham, P.H. and C.P. Vance. 2003. Legumes: importance and constraints for greater use. Plant Physiol. 131: 872–877.

Hauggaard-Nielsen, H., P. Ambus, E.S. Jensen. 2001. Interspecific competition, N use and interference with weeds in pea–barley intercropping. Field Crops Res. 70(2): 101-109.

Hauggaard-Nielsen, H., P. Lachouani, M.T. Knudsen, P. Ambus, B. Boelt, R. Gislum. 2016. Productivity and carbon footprint of perennial grass–forage legume intercropping strategies with high or low nitrogen fertilizer input. Sci. Total Environ. 541: 1339-1347.

Himanen, S., H. Mäkinen, K. Rimhanen, R. Savikko. 2016. Engaging farmers in climate change adaptation planning: assessing intercropping as a means to support farm adaptive capacity. Agriculture. 6(3): 34.

Hinsinger, P., E. Betencourt, L. Bernard, A. Brauman, C. Plassard, J. Shen, X. Tang and F. Zhang. 2011. P for Two, sharing a scarce resource: soil phosphorus acquisition in the rhizosphere of intercropped species. Plant Physiol. 156(3): 1078-1086.

Hu, F., Y. Gan, Q. Chai, F. Feng, C. Zhao, A. Yu, Y. Mu and Y. Zhang. 2016. Boosting system productivity through the improved coordination of interspecific competition in maize/pea strip intercropping. Field Crops Res. 198: 50-60.

Huang, C., Q. Liu, F. Gou, X. Li, C. Zhang, W. van der Werf and F. Zhang. 2017. Plant growth patterns in a tripartite strip relay intercrop are shaped by asymmetric aboveground competition. Field Crops Res. 201: 41-51..

Isaac, M.E., P. Hinsinger and J.M. Harmand. 2012. Nitrogen and phosphorus economy of a legume tree-cereal intercropping system under controlled conditions. Sci. Total Environ. 434: 71-78.

Kolawole, G.O. 2012. Effect of phosphorus fertilizer application on the performance of maize/soybean intercrop in the southern Guinea savanna of Nigeria. Arch. Agron. Soil Sci. 58(2): 189-198.

Kumar, J., A.K. Choudhary, R.K. Solanki and A. Pratap. 2011. Towards marker-assisted selection in pulses: A review. Plant Breed. 130:297-313.

Li, C., Y. Dong, H. Li, J. Shen and F. Zhang. 2016. Shift from complementarity to facilitation on P uptake by intercropped wheat neighboring with faba bean when available soil P is depleted. Sci Rep. 2016; 6: 18663.

Lithourgidis, A., C. Dordas, C. Damalas and D. Vlachostergios. 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Aust. J. Crop Sci. 5(4): 396-410.

Lopes, T., S. Hatt, Q. Xu, J. Chen, Y. Liu and F. Francis. 2016. Wheat (Triticum aestivum L.)-based intercropping systems for biological pest control. Pest Manag. Sci. 72(12): 2193-2202.

Malézieux, E., Y. Crozat, C. Dupraz, M. Laurans, D. Makowski, H. Ozier-Lafontaine, B. Rapidel, S. de Tourdonnet, M. Valantin-Morison. 2009. Mixing plant species in cropping systems: concepts, tools and models: A review. In: Lichtfouse, E., Navarrete, M., Debaeke, P., Véronique, S., Alberola, C. (Eds.), Sustainable Agriculture. Springer Netherlands, Dordrecht, p. 329-353.

Mao, L., L. Zhang, W. Li, W. van der Werf, J. Sun, H. Spiertz and L. Li. 2012. Yield advantage and water saving in maize/pea intercrop. Field Crops Res. 138: 11-20.

Mburu, J. (Ed). 2002. Field crops technical handbook. Government printers- The ministry of agriculture and rural development. Nairobi.

Midmore, D.J. 1993. Agronomic modification of resource use and intercrop productivity. Field Crops Res. 34(3): 357-380.

Mohammed, I.B., O.O. Olufajo, B.B. Singh, S. Miko and S.G. Mohammed. 2008. Evaluation of yield of components of sorghum/cowpea intercrops in the sudan savanna ecological zone. ARPN J. Agric. Biol. Sci. 3(3):30-37

Monti, M., A. Pellicanò, C. Santonoceto, G. Preiti and A. Pristeri. 2016. Yield components and nitrogen use in cereal-pea intercrops in Mediterranean environment. Field Crops Res. 196: 379-388.

Morel, M.A., V. Braña, and S. Castro-Sowinski. 2012. Legume crops, importance and use of bacterial inoculation to increase production. In: Goyal A (ed.), Crop Plant. InTech, doi: 10.5772/37413.

Mousavi, S.R and H. Eskandari. 2011. A general overview on intercropping and its advantages in sustainable agriculture. J. Appl. Environ. Biol. Sci. 1(11)482-486.

Mucheru, M., M. Matussom and J.M. Mugwe. 2009. Potential role of cereal legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. Res. J. Agric. Environ. Manag. 3(3):162-174

Musa, E.M., A.E.A Elsheikh, I.A.M. Ahmed and E.E. Babiker. 2012. Intercropping sorghum (*Sorghum bicolar*L) and cowpea (*Vignaunguiculata*) effect of Bradyrhizobium inoculation and fertilization on mineral composition of sorghum seeds. ISRN Agronomy. 2012: 356183. doi:10.5402/2012/356183

Mwangi, M. 2013.The potential of sorghum in enhancing food security in semi-arid Eastern Kenya. J. Appl. Biosci.71:5786-5799

Naim, A.M., B. Kilali, A.E. Hassan and M.F. Ahamed. 2013. Agronomic evaluation of sorghum and cowpea intercropped at different spacial arrangement. J. Renewable Agric. 1(2):11-16

Nguyen, T.H and A. Blum. 2004. Physiology and biotechnology integration for plant breeding. Marcel Deckker, Inc., New York

Ning, J and J.R. Cumming. 2001. Arbuscular mycorrhizal fungi alter phosphorus relations of broomsedge (*Andropogon virginicus* L.) plants. J. Exp. Bot. 52(362): 1883-1891.

Oseni, O. 2010. Evaluation of sorghum cowpea intercrops productivity in savanna agro ecology using competition indices. J. Argic. Sci. 2(3):229-234.

Otim Otim, G.A., D.N. Mubiru, J. Lwasa, J. Namakula, W. Nanyeenya, O. Robin and J. Elem. 2015. Evaluating permanent planting basin for optimum plant population for maize and beans. J. Environ. Agric. Sci. 2:2

Owuor, C. 2005. Row arrangement and nitrogen effects on growth and yield of sorghum-legume intercrops. Makerere University /RUFORUM. Msc. Thesis,School of Postgraduate Studies, Makerere University Kampala.

Poulton, C and K. Kanyinga. 2014. The politics of revitalising agriculture in kenya. Dev. Policy Rev. 32(s2), s151-s172.

Ramos, M. L. G., R. Parsons, J. I. Sprent and E. K. James. 2003. Effect of water stress on nitrogen fixation and nodule structure of common bean Pesq. agropec. bras. Brasília. 38(3): 339-347.

Rao, P.S., C. G. Kumar, R. S, Prakasham, A. U. Rao and B. S. Reddy. 2015. Sweet Sorghum: Breeding and bioproducts. In "Industrial crops" (V. Cruz and D. Dierig, eds.), Vol. 9, p. 1-28. Springer New York.

Ren, Y., J. Liu, Z. Wang and S. Zhang. 2016. Planting density and sowing proportions of maize–soybean intercrops affected competitive interactions and water-use efficiencies on the Loess Plateau, China. Eur. J. Agron. 72: 70-79.

Richards, R. 2000. Selectable traits to increase crop photosynthesis and yield of grain crops. J. Exp. Bot. 51(Suppl 1): 447-458.

Sanginga, N., K. Dashiell, J. Diels, B. Vanlauwe, O. Lyasse, R.J. Carsky, S. Tarawali, B. Asafo-Adjei , A. Menkir, S. Schulz, B.B. Singh, D. Chikoye, D. Keatinge and R. Ortiz. 2003. Sustainable resource management coupled to resilient germplasm to provide new intensive cereal-grain legume-livestock systems in the dry savanna. Agric. Ecosyst. Environ. 100: 305–314

Shuaibu, Y.M., A.A. Garba and N. Voncir. 2015. Influence of legume residue and nitrogen fertilization on the growth and yield of sorghum. African J. Food Agric. Nutr. Dev. 15(3):.2015.

Singh, B.B., H.A. Ajeigbe, S.A. Tarawali, S. Fernandez-Rivera and M. Abubakar. 2003. Improving the production and utilization of cowpea as food and as fodder. Field Crops Res. 84:169–177

Singh, H.P., D.R. Batish, R.K. Kohli. 2003. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. Crit. Rev. Plant Sci. 22(3-4): 239-311.

Stern, W.R. 1993. Nitrogen fixation and transfer in intercrop systems. Field Crops Res. 34(3): 335-356.

Taffouo, V.D., B. Ngwene, A. Akoa and P. Franken. 2014. Influence of phosphorus application and arbuscular mycorrhizal inoculation on growth, foliar nitrogen mobilization, and phosphorus partitioning in cowpea plants. Mycorrhiza. 24: 361.

Trenbath, B.R. 1993. Intercropping for the management of pests and diseases. Field Crops Res. 34(3): 381-405.

Wahbi, S., Y. Prin, J. Thioulouse, H. Sanguin, E. Baudoin, T. Maghraoui, K. Oufdou, C. Le Roux, A. Galiana, M. Hafidi, R. Duponnois. 2016. Impact of wheat/faba bean mixed cropping or rotation systems on soil microbial functionalities. Front. Plant Sci. 7: 1364.

Weisany, W., S. Zehtab-Salmasi, Y. Raei, Y. Sohrabi, and K. Ghassemi-Golezani. 2016a. Can arbuscular mycorrhizal fungi improve competitive ability of dill + common bean intercrops against weeds? Eur. J. Agron. 75: 60-71.

Weisany, W., Y. Raei, S.Z. Salmasi, Y. Sohrabi and K. Ghassemi-Golezani. 2016b. Arbuscular mycorrhizal fungi induced changes in rhizosphere, essential oil and mineral nutrients uptake in dill/common bean intercropping system. Ann. Appl. Biol. 169(3): 384-397.

Xia, H.-Y., Z.-G. Wang, J.-H. Zhao, J.-H. Sun, X.-G. Bao, P. Christie, F.-S. Zhang and L. Li. 2013. Contribution of interspecific interactions and phosphorus application to sustainable and productive intercropping systems. Field Crops Res. 154: 53-64.

Xue, Y., H. Xia, P. Christie, Z. Zhang, L. Li and C. Tang. 2016. Crop acquisition of phosphorus, iron and zinc from soil in cereal/legume intercropping systems: a critical review. Ann. Bot.117(3):363-377.

Yu, Y., S. Tjeerd-Jan, D. Makowski and W. van der Werf. 2015. Temporal niche differentiation increases the land equivalent ratio of annual intercrops: A meta-analysis. Field Crops Res. 184: 133-144.

Zougmore, R., F.N. Kambou, K. Ouattara and S. Guillobez. 2000. Sorghum-cowpea intercropping: an effective technique against run-off and soil erosion in the Saleh Region. Arid Soil Res. Rehabil. 14(4):329-342.