Journal of Agricultural Science and Food Technology
Vol. 3 (4), pp. 64-77, July, 2017
ISSN: 2465-7522
Review
http://pearlresearchjournals.org/journals/jasft/index.html

Tillage And Relay Intercropping Effect On Yield And Yield Components Of Upland Rice

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Accepted 24 March, 2017

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ABSTRACT

Rice remains a major staple food crop for almost half of the world's population. It is the third most important cereal in Kenya after maize and wheat and its demand continues to grow. A study was conducted to establish the yield response of upland rice (NERICA 1) to tillage and relay intercropping in vertisols of Mwea, Kenya. Three tillage methods; hand hoe (HH), broad bed (BB) and zero tillage (ZT); and five cropping systems; rice sole crop (RSC), chickpea sown same time with rice crop (CPST), chickpea relayed two weeks after sowing of the rice crop (CPR2), chickpea relayed four weeks after sowing of the rice crop (CPR4) and chickpea relayed six weeks after sowing of the rice crop (CPR6) were tested. The experiment was laid out in split-plot design with 3 replications. The results indicate performance advantage in intercropped rice compared to its sole crop. Intercropping resulted in greater number of panicles per m2, heavier grains (1000 grain weight) and increased above ground biomass yield especially when chickpea was relayed 2 to 4 weeks after sowing rice. Tillage by cropping system interaction was highly significant ($p<0.01$) for grain weight in season II. The heaviest grains (26 g/1000seeds) were recorded in CPR6 under BB tillage. However there were yield variations in all seasons across cropping systems. This study therefore establishes that chickpea can be relay intercropped in upland rice at least 2 to 4 weeks after sowing the rice crop without significant effect on rice performance.

Key words: Cropping systems, NERICA and Vertisols.

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INTRODUCTION

Rice (*Oryza sativa*) is a major staple food crop for almost half of the world population mainly living in the developing countries (Pandey et al., 2010). The crop is the third most important cereal in Kenya after maize and wheat (MOA and JICA, 2011); where it is mainly grown under irrigation. However, given the challenges of climate change production of upland rain-fed rice varieties has become very important. Thus the New Rice for Africa (NERICA) varieties were introduced in the country in 2002 (MOA and JICA, 2011). Spatial and temporal variations in rainfall are critical weather parameters in rain-fed rice ecologies as they impact on stand establishment and growth duration (Narayanan, 2004). Although water deficit reduces plant height, tiller numbers and leaf area, the crop can recover if water is available before flowering without much loss in yield (Narayanan, 2004). However, moisture deficit during grain filling reduces grain yield drastically irrespective of normal rainfall during the preceding growth stages. To some extent, yield variations are mainly affected by rainfall received during the grain filling stage (Arraudeau and Vergara, 1988; Gupta et al., 2000). During ripening, rice grain increases in size and weight as starch and sugars are translocated from the culms and leaf sheaths (Moldenhauer and Slaton, 2001; MOA and JICA, 2011). Tillage is an important aspect in crop performance because it enhances efficient fertilizer use, soil porosity, aeration, moisture and nutrient availability (Ampofo, 2006). Thus, tillage methods that enhance soil moisture conservation are recommended especially under semi-arid conditions (Onyari et al., 2010; Kalinda et al., 2015).

The advantages of zero tillage (undisturbed soil) and minimum tillage (which involves minimum soil disturbance) in improving soil moisture availability have been reported in annual crop yields like maize (*Zea mays*) and wheat (*Triticum aestivum* L.) (Gicheru et al., 2005; Govaerts et al., 2007; Aboudrare et al., 2006). These tillage methods enhance infiltration and soil moisture retention and hence improved crop performance more so when crop residue is retained (Govaerts et al., 2007; Pramanik et al., 2014; Kalinda et al., 2015). On the other hand, cracks in Vertisols have a significant role in soil water dynamics as they enhance infiltration into deeper soil layers in a dry and undisturbed soil (Elias et al., 2001). An increase in number of spikes/m^2 has been observed under zero tillage compared to reduced and conventional tillage in wheat with no effect on grain yields (Usman et al., 2013). Similar findings have been stated by Patil et al. (2016). However, higher wheat yields have been obtained under no-tillage compared to conventional tillage under rain-fed conditions in Italy (De Vita et al., 2007). This effect was attributed to lower evaporation combined with enhanced soil water availability in no-tillage. Munoz-Romero et al. (2010) also reports similar finding in vertisols of the Mediterranean. Greater above ground biomass, N uptake in corn and early growth, under no-till compared to conventional tillage system has been reported (Eghball and Power, 1999). In the same study there was greater early growth and yield in no-till than conventional tillage suggesting greater water storage in the no-till system. Alizadeh and Allameh (2015) have shown that tillage influences plant height, 1000 grains weight, grain yield and yield components in canola. Besides tillage, sowing method also influences yield and maturity in rice with direct seeding of sprouted seed being superior to direct seeding of dry seed and transplanting (Rana et al., 2014).

In a study involving conventional and conservation tillage treatments, Patil et al. (2016) observed no significant effect on crop yield. This was attributed to receipt of sufficient rainfall coupled with deep soils hence satisfying crop water requirements. Similarly, Iktoo et al. (2007) observed a significant increase in maize yields when Broad Bed and Furrow (BBF) were used to drain excess water in vertisols in Kenya. Erkossa et al. (2006) have also shown that BBF influences number of days to heading and plant height compared to ridge and furrow in wheat as observed in vertisols in Ethiopia.

These researchers observed that BBF resulted in increased days to heading, reduced plant height and increased number of tillers per plant as opposed to ridge and furrow which resulted in lowest number of days to heading and highest plant height in wheat. In a maize/bean intercrop, Karuma et al. (2016) observed seasonal variations in tillage effects on growth and yields in both crops. They attributed this to the seasonal rainfall differences as well as short term soil management effects.

Saito et al. (2010) observed an increase in upland rice yields both under no-tillage and manual tillage practices when natural fallow vegetation was replaced with Stylo (*Stylo guinanensis*) in southern Benin. Usman et al. (2014) observed significant effects of tillage on panicles/m^2, 1000-grain weight and grain yield in rice in Pakistan. In this case the highest number of panicles/m^2 was recorded in zero tillage where straw was retained. Generally cereal/legume intercropping systems increase dry matter production and grain yield compared to their respective sole crops (Fujita and Ofosu, 1994; Arshad and Rananmukhaarachchi, 2012). The benefits of nutrient availability, retrieval and uptake in cereal-legume intercrops have been reported (Rerkasem et al., 1988; Fujita et al., 1990; Tobita et al., 1994; Karpenstein-Machan and Stuelpnagel, 2000; Hauggaard-Nielsen et al., 2001; Sharma and Gupta, 2002; Shili-Touzi et al., 2010; Matusso et al., 2014). Sullivan (2003) has shown that staggered maturity dates as well as development periods in intercrops take advantage of variations in peak resource demands for nutrients, water and light.

The effect of relay intercropping of legume on above ground biomass of wheat has been established (Ammosse et al., 2013). In this study the amount of N uptake, wheat biomass and grain yield varied with the type of the legume used as an intercrop. Chen et al. (2004) have also reported an increased biomass production by barley (Hordeum vulgare v. Tipper) and pea (Pisum sativum) in barley-pea intercropping compared to their sole crops. Intercropping legumes with cereals contributes some nitrogen to the cereal component through residual nitrogen (Adu-Gyamfi et al., 2007). Lawrence and Gohain (2011) observed a yield advantage in rice/green gram intercrop planted at 4:1 ratio compared with their sole crops. A study by Saito et al. (2006) to identify an appropriate time of seeding Stylo fodder in upland rice with minimal effect on grain yield revealed that relay seeding stylo 15 days after rice sowing offered no competition effect. However rice yield was decreased by half when stylo was seeded at the same time with rice. A decrease in number of panicle bearing tillers and 1000-grain weight among intercropping systems compared to sole rice crops has been reported (Ahmad et al., 2007). Bitew and Asargew (2014) present a no effect on growth, yield and yield components of rice when chickpea was relay intercropped between rows of transplanted rice in Ethiopia. It is documented that although rice grain weight is genetically controlled it is also influenced by the environment during grain filling process (Kausar et al., 1993). Koki et al. (2008) observed an increased N uptake by subsequent rice crop when stylo was relay-intercropped in rain-fed rice fields in Thailand. Chu et al. (2004) established that intercropping rice with peanut significantly increased N content in rice and that intercropping wheat with peanut increased wheat grain yields. Differences in the competitive ability of legumes species exists since Marrioti et al. (2009) report variations in nitrogen concentration and yield in common vetch and white lupin intercropped with wheat and barley. Thus the cereal may be a better competitor for soil mineral N than the legume where the legume compensates through Biological Nitrogen Fixation if effective strains of Rhizobium are present in the soil. In another study involving intercropping of barley and peas it was evident that barley was a better competitor for soil mineral N resulting to higher grain and N uptake in barley comparable to its sole crop (Hauggard-Nielsen and Jensen, 2001). Martin et al. (1991) also confirmed that transfer of nitrogen from nodulating soybean to non-nodulating soybean and maize occurs. The current study aimed at establishing how different tillage methods combined with relay intercropping chickpea in rice affect rice performance.

MATERIALS AND METHODS

Description of the Study Site

The study was carried out at the Mwea Irrigation and Agriculture Development (MIAD) center within Mwea region of Kirinyaga County in Central Kenya. The site is in a transition zone between middle highlands 5 (UM5) and lower highlands (LH4) agro ecological zone thus; it has a hot and dry climate most of the year. It is characterized by bimodal rainfall pattern with the short rains from October to December (OND) and the long rains from March to May (MAM). The major Agro-ecological Zone (AEZ) is Lower Midlands (LM3 and LM4) occupying an area of 132,600 and 332, 700 hectares (ha), respectively (Jaetzold, 2006). The other AEZs are Upper Midlands (UM3 and UM4) with an area of 2,100 and 37,600 ha, respectively. The dominant soils are Vertisols. These soils are imperfectly drained, very deep, dark grey to black with firm to very firm consistence when moist and very sticky and plastic when wet. They are of low to moderate fertility (Jaetzold, 2006).

Experimental Design and Treatments

The effect of three tillage methods and relay intercropping on growth and yield of upland rice was assessed in the 2015 to 2016 growing seasons. The tillage methods tested were zero tillage (ZT) (undisturbed soil where no tillage was done); hand hoe (HH) (flat beds prepared with a hand hoe) and broad beds (BB) (2m wide raised beds prepared manually). The relay intercropping systems tested were rice sole crop (RSC), chickpea sown same time with the rice crop (CPST), chickpea relayed two weeks after sowing of the rice crop (CPR2), chickpea relayed four weeks after sowing of the rice crop (CPR4) and chickpea relayed six weeks after sowing of the rice crop (CPR6). The experiment was laid out in split-plot design with tillage as the main plot and cropping system as the sub plot replicated three times. The field was laid out in 3x4 m plots. Desi chickpea (ICCV 97105) and upland rice (NERICA 1) were used as the test crops. Rice was planted at a spacing of 30 x 20 cm. RSC and CPST were planted on the onset of the rainy season after which chickpea was relay cropped at two weeks intervals up to 6 weeks. One row of chickpea was planted between the two rows of rice (1:1 ratio) in each relay. Prior to sowing, rice seeds were pre-germinated by first soaking in cold water for 24 h after which they were removed from the water then covered with gunny bags and incubated for 48 h in a warm area. Two to three pre-germinated seeds of rice were planted per hill. On the other hand two seeds of chickpea were directly sown per hill. Plants were later thinned to one plant per hill in both crops.
The rice data was determined as follows:

Number of Panicles per m^2

A one metre square quadrant was randomly placed in each plot and the total number of panicles within the quadrant counted.

1000 Grain Weight

Two samples of 1000 seeds were counted using an automatic seed counter for each treatment and then weighed in grams (g), after which the average weight was computed.

Biomass Yield

A one metre square quadrant was randomly placed in the plot and the plants within the quadrant harvested inclusive of panicles with grains. These plants were then placed in well labeled paper bags after which they were sun-dried before weighing with an electronic balance. Total weight of the above ground biomass was recorded in grams and later converted into kilograms per hectare (kg/ha).

Grain Yield

After taking the weight of the above ground biomass the plants harvested within the quadrant were threshed by hand. The grains were then weighed in grams with an electronic balance and later converted into kg/ha.

Statistical Analysis

The yield and yield components data was subjected to Analyses of Variance (ANOVA) using Genstat for *Windows* 15th Edition software. Fishers Protected Least Significance Difference (LSD) was used to test for significance at $p \leq 0.05$.

RESULTS AND DISCUSSION

Effect Of Tillage And Cropping System On Number Of Panicles Per m^2 In Upland Rice (NERICA 1)

Tillage by cropping system interaction for number of panicles/m^2 was highly significant ($p<0.001$) in season II and III but not in season I (Table 1). Tillage method influenced ($p<0.01$) the number of panicles/m^2 in season I and III but not season II. The number of panicles/m^2 was also significantly ($p<0.05$) affected by the relay intercropping system in all the three seasons. The RSC yielded the highest number of panicles/m^2 under all tillage systems in season I. CPR6 produced the highest number of panicles/m^2 (98panicles/m^2) under BB tillage compared to CPR2 and CPR4 in season I. The CPST was second best under this tillage method with 74panicles/m^2. The same trend was observed in season III. Thus the highest panicle yield was recorded in CPR6 with 133 panicles followed by the CPST with 130 panicles under BB tillage. CPST was also the best in season II with 249 panicles/m^2 followed by CPR2 with 227 panicles/m^2 under BB tillage. This high panicle production could be attributed to the higher rainfall (747.8 mm) received in season II which favoured rice growth compared to 506.2 mm and 558.0 mm in seasons I and III, respectively. In these two cropping systems (CPR6 and CPST) chickpea performed poorly which could have favoured the rice crop by reducing competition for nutrients, moisture and light. In the HH tillage, the highest number of 120 panicles per m^2 was recorded in CPR4 in season 1 followed by CPR2 with 118 panicles/m^2.

The trend was different in season II where CPST yielded 231 panicles under HH among the relay systems. However this was less than the RSC (241panicles/m^2). Although the RSC had the highest number of panicles/m^2 among all cropping systems under HH tillage in season III, CPR6 was the best among the relays producing 152 panicles/m^2. A decreasing trend of CPR4>CPR2>CPST was also observed in the same season under this tillage. This performance in CPR6 was attributed to less competition between the components crops since chickpea did not do well at this stage probably due to over shading by the rice crop. Further investigations on the spatial arrangement of these two crops are therefore necessary. Such investigations will establish the appropriate spacing and pattern of these crops in the intercrop system. The RSC yielded more panicles/m^2 than all the cropping systems in season I (118) and III (188) under the ZT. This may be so probably because of less competition for nutrients, water and light in the sole crop compared to the intercrops in both seasons. This concurs with the results by Ahmad et al. (2007) who observed reduction in panicle bearing tillers in intercropped rice compared to its sole crop. Usman et al. (2013) also observed an increase in spikes/m^2 in wheat grown under zero tillage compared to minimum tillage which they attributed to increased soil organic matter and total soil N. In season I CPR4 performed better than the other relay systems with 111 panicles/m^2 followed by CPR2 (109 panicles/m^2) under ZT. The same CPR4 performed better than the rice in the other relays with 166 panicles/m^2 followed by CPST (165 panicles) under ZT in season III. Thus RSC yielded the highest panicles (188 panicles/m^2) under ZT. Ahmad et al. (2007) also reported a reduction of panicle bearing tillers among rice/legume intercropping systems compared to the sole crop. Season II results indicated a better performance within the intercropping systems than the rice sole crop. In this case there was a decreasing trend of CPR2>CPR4>CPST>RSC>CPR6 under ZT.

The rice performance in CPR2 in season II may indicate some benefits of intercropping bearing in mind that this season received higher rainfall than the other two seasons. This probably suggests that when moisture is not a limiting factor, nutrient availability and uptake by the rice crop within the intercrop is also improved. Similar arguments on nutrient availability, retrieval and uptake in cereal-legume intercrops have been previously raised (Karpenstein-Machan and Stuelpnagel, 2000; Hauggaard-Nielsen et al., 2001; Sharma and Gupta, 2002; Shili-Touzi et al., 2010; Matusso et al., 2014). When the number of panicles/m^2 was averaged across cropping systems, HH tillage had the highest number of panicles/m^2 (115) in season I while ZT had the highest panicles/m^2 (158) in season III. Though tillage did not show significant ($p>0.05$) effect on number of panicles/m^2 in season II, ZT still had more panicles/m^2 than HH and BB. This suggests more moisture availability and better crop growth within the ZT system compared to the other two tillage methods. This agrees with Usman et al. (2014) who reported higher panicle yield under no-till in Pakistan. The advantage of moisture conservation and improved crop performance in minimum and zero tillage systems have also been previously reported (Gicheru et al., 2005; Govaerts et al., 2005 Aboudrare et al., 2006; Govaerts et al., 2007; De Vita et al., 2007; Munoz-Romero et al., 2010; Pramanik et al., 2014; Kalinda et al., 2015).

Table 1. Effect of tillage and relay intercropping on number of panicles/m2 in upland rice (NERICA 1) in season I, II and III.

Season I							**Season II**						**Season III**					
Cropping system																		
Tillage	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Means**	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Means**	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Means**
BB	74	72	67	98	108	84	249	227	159	204	193	207	130	120	133	118	107	122
HH	105	118	120	110	124	115	231	193	150	207	241	204	127	139	145	152	159	144
ZT	101	109	100	111	118	108	217	222	221	179	198	207	165	151	166	117	188	158
Means	93	99	96	106	117	102	232	214	177	197	211	206	141	137	148	129	152	141
LSD (p ≤0.05) T				13.8*					25.49ns						14.6*			
LSD (p ≤0.05) CS			11.91*						14.19**						11.7*			
LSD (p ≤0.05) T x CS				21.02ns					29.68**						21.1**			
CV%				12					7.1						8.6			

*, **, ns denotes significant at 0 05, 0.001 and not significant respectively. T=tillage; CS=cropping system. Treatments: CPST= chickpea sown same time with the rice crop, CPR2= chickpea relayed 2 weeks after sowing rice, CPR4= chickpea relayed 4 weeks after sowing rice, CPR6= chickpea relayed 6 weeks after sowing rice, RSC= rice sole crop, BB= broad beds, HH=hand hoe and Z= zero tillage.

Table 2. Effect of tillage and cropping system on 1000 seeds weight in upland rice (NERICA 1) in season I, season II and season III.

Season I							**Season II**						**Season III**					
						Cropping system												
Tillage	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Means**	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Mean**	**CPST**	**CPR2**	**CPR4**	**CPR6**	**RSC**	**Mean**
BB	20.43	18.67	18.27	18.80	18.80	18.99	25.37	24.83	25.40	26.00	23.77	25.07	18.87	19.10	18.57	19.27	19.30	19.02
HH	21.53	19.87	19.90	21.40	20.47	20.63	24.37	24.70	25.57	24.97	24.77	24.87	20.33	19.13	20.70	21.30	19.90	20.27
ZT	20.50	20.73	20.60	17.07	17.23	19.23	23.10	22.63	25.80	25.70	21.53	23.75	19.80	21.57	20.77	17.53	17.90	19.51
Means	20.82	19.76	19.59	19.09	18.83	19.62	24.28	24.06	25.59	25.56	23.36	24.57	19.67	19.93	20.01	19.37	19.03	19.50
LSD (p ≤0.05) T				3.712ns					2.658ns						3.645ns			
LSD (p ≤0.05) CS			2.453ns						1.188**						1.858ns			
LSD (p ≤0.05) T x CS				4.732ns					2.84**						4.084ns			
CV%				12.9					5						9.7			

*, **, ns denotes significant at 0 05, 0.001 and not significant respectively. T=tillage; CS=cropping system. Treatments: CPST= chickpea sown same time with the rice crop,CPR2= chickpea relayed 2 weeks after sowing rice, CPR4= chickpea relayed 4 weeks after sowing rice, CPR6= chickpea relayed 6 weeks after sowing rice, RSC= rice sole crop, BB= broad beds, HH=hand hoe and ZT= zero tillage (Undisturbed soil).

Effect Of Tillage And Cropping System On 1000 Seed Weight In Upland Rice (NERICA 1)

Tillage and cropping system had no significant effect ($p>0.05$) on the 1000 seed weight in upland rice (NERICA 1) in season I and III. On the contrary Alizadeh and Allameh (2015) observed that tillage increased 1000 grain weight in canola. However cropping system and tillage by cropping system interaction was highly significant ($p<0.01$) for 1000 seed weight in season II (Table 2). CPR6 recorded the heaviest grains (26 g/1000 seeds) under BB tillage in season II followed by CPR4 (25.4g/1000 seeds). This observation could indicate some advantage of cereal/legume intercropping since the RSC gave the lightest grains (23.77g/1000 seed weight) under the same tillage in this season. The heaviest grains under HH tillage were obtained in CPR4, recording a mean weight of 25.57g in season II. CPR4 still had the heaviest grains (25.8 g) under ZT in this season. Moisture and temperature during ripening stage affect translocation of N from vegetative parts to the grains thus influencing grain weight (Arraudeau and Vergara, 1988; Gupta et al., 2000; Moldenhauer and Slaton, 2001; MOA and JICA, 2011). Moisture was not a limiting factor in season II due to the high rainfall of 704.8 mm received compared to 506.2 mm in season I and 558.0 mm in season III. This could explain the positive effect on grain weight compared to the other two seasons. Kausur et al. (1993) have also shown that grain weight is influenced by the environment during grain filling process. Likewise Usman et al. (2014) also observed that tillage affected 1000 grain weight in wheat grown under zero tillage. This observation could also be attributed to advantages of intercropping in enhancing nutrient uptake as compared to sole cropping as stated by Adu-Gyamfi et al. (2007) and Koki et al. (2008). Similarly Chu et al. (2004) observed an increase in N content in rice grains when intercropped with peanuts.

Effect Of Tillage And Cropping System On Above Ground Biomass Yield (kg/ha) In Upland Rice (NERICA 1)

Tillage by cropping system interaction was statistically significant ($p<0.05$) for above ground biomass yield in all the seasons. CPR2 and CPST recorded the highest (4,412 kg/ha) and lowest (3070.3 kg/ha) above ground biomass yield, respectively in season I under BB tillage (Figure 1). Under HH tillage, CPR4 yielded the highest above ground biomass (6035.7 kg/ha) compared to the rice in the other relays in this season. This was second to the RSC (6104kg/ha) under this tillage. CPR2 out yielded the other relayed systems in season I and II with 7203.3 kg/ha and 8095 kg/ha biomass yield, respectively under ZT. This performance under ZT may be an indicator of sufficient moisture in this tillage as argued by De Vita et al. (2007) as well as Munoz-Romero et al. (2010). In season III CPR2 was second best with a biomass yield of 4994 kg/ha after CPR4 (5471kg/ha) under ZT. The general observation in season I and III was that ZT and BB tillage recorded the highest and lowest biomass yields, respectively (Figure 1) in all the cropping systems. However, this trend was not observed in season II where CPST and CPR6 yielded comparably higher biomass under BB than under the other tillage methods. Sufficient moisture in season II and possibly better nutrient availability and uptake may be the reason for this high yield under BB. This effect has also been mentioned by Onyari et al. (2010) Kalinda et al. (2015). An increase in rice biomass yield in rice-cowpea intercrop was observed by Ogutu et al. (2012). Chen et al. (2004) have also reported an increased biomass production by barley and pea in barley-pea intercropping compared to their sole crops.

Effect Of Tillage And Cropping System On Upland Rice (NERICA 1) Grain Yield (kg/ha)

Significant ($p<0.05$) tillage by cropping system interactions for grain yield were observed in all the three seasons. RSC had the highest grain yield (1351kg/ha) under BB tillage in season I. CPR6 recorded the highest grain yield in season I (1272 kg/ha) and III (904 kg/ha) compared to CPR2 and CPR4 under this tillage. The same cropping system (CPR6) was second best under BB tillage in season II with 2675 kg/ha; in this season CPST recorded the best yields of 2814 kg/ha. These findings echo the sentiments by Fujita and Ofosu (1994) that cereal-legume intercrops increase dry matter production and grain yields. CPR4 had the least grain yields compared to CPR2 and CPR6 under BB tillage in all the three seasons with 627 kg/ha in season I, 2124 kg/ha in season II and 750 kg/ha in season III. These low yields in CPR4 were perhaps due to the stiff competition for water and nutrients at this stage since chickpea performance was best under BB tillage. Under HH tillage, CPST out yielded all the cropping systems with 1634 kg/ha and 3009 kg/ha in season I and II, respectively (Figure 2). The least grain yields under HH tillage were attained in CPR2 (1318 kg/ha) in season I and CPR6 (2249 kg/ha) in season II. In season III, the RSC recorded the highest grain yield (1108 kg/ha) followed by CPR6 (961 kg/ha) while the least was realized in CPST (909 kg/ha) under HH tillage. The highest grain yield under ZT in season 1 was recorded in CPR2 (1880 kg/ha) while CPST had the least (862 kg/ha). This was followed by CPR4 where 1671kg/ha were realized; which was higher than the RSC (1490 kg/ha) under this tillage in this season.

The observed grain yield response to tillage in season 1 was HH>ZT>BB. On the contrary, CPST gave the highest yield under HH tillage at 3001kg/ha; followed by CPR4 (2706 kg/ha) in season II. CPR6 gave the least yield at 2249 kg/ha under the HH tillage. It is notable that season

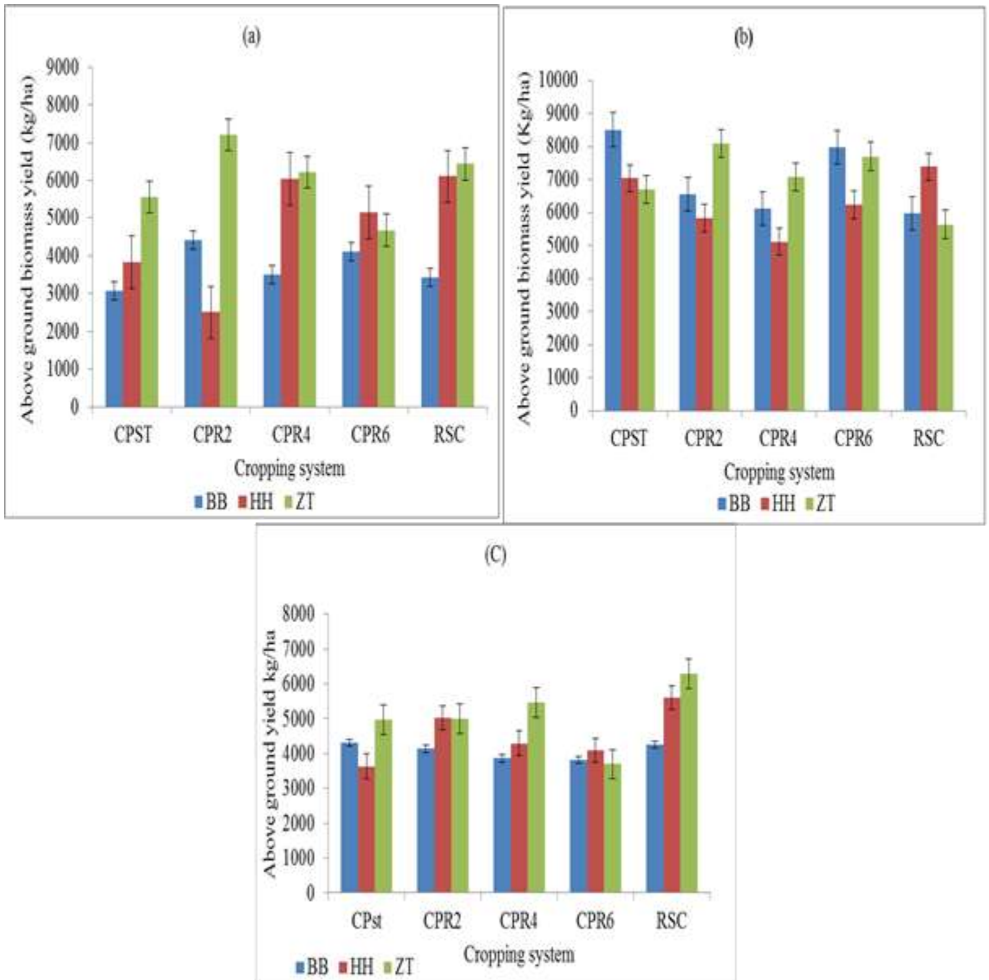

Figure 1. Above ground biomass yield (kg/ha) in upland rice (NERICA 1) as affected by tillage and relay intercropping in season I (a), season II (b) and season III (c). Treatments: CPST= chickpea sown same time with the rice crop, CPR2= chickpea relayed 2 weeks after sowing rice, CPR4= chickpea relayed 4 weeks after sowing rice, CPR6= chickpea relayed 6 weeks after sowing rice, RSC= rice sole crop, BB= broad beds, HH=hand hoe and ZT= zero tillage.

II received higher rainfall than the other two seasons hence moisture may not have been a limiting factor resulting in better performance in the rice crop. There was general trend in season III where the highest grain yield was recorded under the ZT and the least under BB tillage among all the relay intercropping systems. However in the RSC the highest grain yield (110 8kg/ha) was achieved under HH tillage in this season. During the same season, CPR6 had the highest yield (904 kg/ha) under BB tillage whose performance was better than the RSC (846 kg/ha). The CPST recorded the highest yield of 1133 kg/ha under ZT in season III followed by CPR2 with 1059 kg/ha. In season III the RSC had the least yield under ZT. High rice yields were realized in other related studies by Saito et al. (2010) in Benin. These yield variations may also have been affected by rainfall received during the grain filling stage as stated by Gupta et al. (2000). In this case the grain yields realized in season I and III may have been affected by the fact that rainfall was poorly distributed during these two seasons. This could also explain the seasonal yield variations observed during this study. It is also documented that although rice grain weight is genetically controlled, it is also influenced by the environment during grain filling process (Kausar et al., 1993). Similarly Koki et al. (2008) observed an increased N uptake by subsequent rice crop when stylo was relay-intercropped in rain-fed rice fields in Thailand. This also reflects on the findings by Chu et al. (2004) that intercropping rice with peanut increases nutrient uptake in rice and that intercropping wheat with peanut increases wheat grain yields.

ACKNOWLEDGEMENTS

We are grateful for the contribution made by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) through provision of chickpea seeds and the

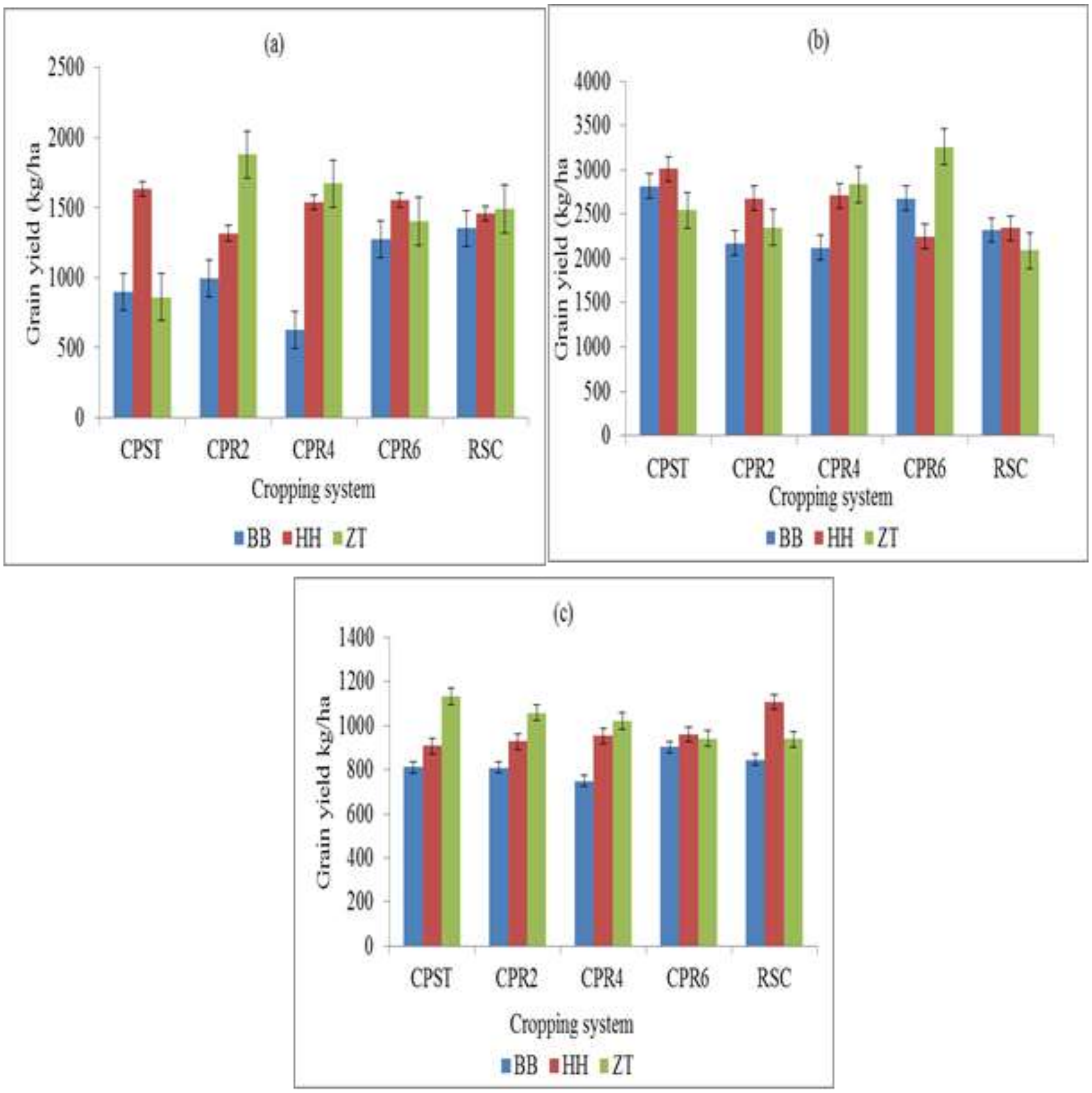

Figure 2. Grain yield (kg/ha) in upland rice (NERICA 1) as affected by tillage and relay intercropping in season I (a), season II (b) and season III (c), Treatments: CPST= chickpea sown same time with the rice crop, CPR2= chickpea relayed 2 weeks after sowing rice, CPR4= chickpea relayed 4 weeks after sowing rice, CPR6= chickpea relayed 6 weeks after sowing rice, RSC= rice sole crop, BB= broad beds, HH=hand hoe and ZT= zero tillage.

German Academic Exchange Service for the financial support during the entire study.

CONCLUSION AND RECOMMENDATION

It was evident that upland rice responds to tillage and legume-intercropping. The results from this study revealed significant tillage x cropping system interactions for yield parameters. Overall the rice performance was best where there was less competition in the intercrop mainly due to poor performance of chickpea crop. Rainfall amount and distribution as well as temperature are likely to have played a major role in determining rice performance across seasons. Again some benefits of cereal-legume intercropping were observed; thus in some instances the intercropped rice did better than the rice sole crop. This calls for further investigations. The inconsistences across seasons call for long term investigations more so under optimum moisture and temperature conditions. Further studies on the spatial arrangements of these two crops in an intercrop system are also necessary.

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APPENDIX

ANOVA tables

Variate: 1000 seed weight: Season I (Long rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	7.394	3.697	0.28	
Rep.tillage stratum					
Tillage	2	23.614	11.807	0.88	0.482
Residual	4	53.634	13.409	2.11	
Rep.tillage.cropping_system stratum					
Cropping_system	4	21.290	5.323	0.84	0.515
Tillage.cropping_system	8	37.962	4.745	0.75	0.651
Residual	24	152.552	6.356		
Total	44	2.96.446			

Variate: 1000 seed weight season II (Short Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	1.865	0.933	0.14	
Rep.tillage stratum					
Tillage	2	15.184	7.592	1.10	0.415
Residual	4	27.491	6.873	4.61	
Rep.tillage.cropping_system stratum					
Cropping_system	4	34.509	8.627	5.79	0.002
Tillage.cropping_system	8	20.067	2.508	1.68	0.154
Residual	24	35.764	1.490		
Total	44	134.880			

Variate: 1000 seed weight Season III (Long Rain 2016).

Source of variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	1.367	0.684	0.05	
Rep.tillage stratum					
Tillage	2	11.959	5.980	0.46	0.660
Residual	4	51.700	12.925	3.54	
Rep.tillage.cropping_system stratum					
Cropping_system	4	5.941	8.485	0.41	0.802
Tillage.cropping_system	8	40.396	5.050	1.38	0.253
Residual	24	87.567	3.649		
Total	44	198.930			

Variate: Number of panicles/m^2: Season II (Short Rain 2015)

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	1894.5	947.3	1.50	
Rep.tillage stratum					
Tillage	2	83.2	5.980	0.46	0.660
Residual	4	2529.1	12.925	3.54	
Rep.tillage.cropping_system stratum					
Cropping_system	4	1564.9	8.485	0.41	0.802
Tillage.cropping_system	8	18162. 4	5.050	1.38	0.253
Residual	24	5101.7	3.649		
Total	44	43416.8			

Variate: Number of panicles/m^2: Season II (Short Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	1925.9	962.9	4.65	
Rep.tillage stratum					
Tillage	2	9825.4	4912.7	23.74	0.660
Residual	4	827.7	206.9	1.42	
Rep.tillage.cropping_system stratum					
Cropping_system	4	2998.2	749.6	5.14	0.004
Tillage.cropping_system	8	8572.0	1071.5	7.35	<.001
Residual	24	3499.6	145.8		
Total	44	27648.9			

Variate: Above ground biomass yield kg/ha Season I (Long Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	215353.	107677.	0.82	
Rep.tillage stratum					
Tillage	2	40207386.	20103693.	152.87	<.001
Residual	4	526020.	131505.	0.64	
Rep.tillage.cropping_system stratum					
Cropping_system	4	8357016.	2089254.	10.24	<.001
Tillage.cropping_system	8	34660249.	4332531.	21.23	<.001
Residual	24	4897320.	204055.		
Total	44	88863344.			

Variate: Above ground biomass yield kg/ha Season II (Short Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	494036.	247018.	1.33	
Rep.tillage stratum					
Tillage	2	5112999.	2556500.	13.79	0.016
Residual	4	741816.	185454.	1.76	
Rep.tillage.cropping_system stratum					
Cropping_system	4	12024040.	3006010.	28.59	<.001
Tillage.cropping_system	8	24577233.	3072154.	29.22	<.001
Residual	24	2523177.	105132.		
Total	44	45473302.			

Variate: Biomass yield kg/ha Season III (LR 2016).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	756056.	378028.	2.23	
Rep.tillage stratum					
Tillage	2	7688735.	3844367.	22.71	0.007
Residual	4	677242.	169310.	0.70	
Rep.tillage.cropping_system stratum					
Cropping_system	4	11215100.	2803775.	11.58	<.001
Tillage.cropping_system	8	7451864.	931483.	3.85	0.005
Residual	24	5812950.	242206.		
Total	44	33601947.			

Variate: Rice grain yield kg/ha season I (Long Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	47400.	23700.	1.40	
Rep.tillage stratum					
Tillage	2	2066245.	1033122.	16.17	0.001
Residual	4	67561.	16890.	0.28	
Rep.tillage.cropping_system stratum					
Cropping_system	4	573707.	143427.	2.36	0.082
Tillage.cropping_system	8	2376201.	297025.	4.89	0.005
Residual	24	1456527.	60689.		
Total	44	6587641.			

Variate: Rice grain yield kg/ha season II (Short Rain 2015).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	96743.	48371.	1.49	
Rep.tillage stratum					
Tillage	2	344939.	172469.	5.31	0.075
Residual	4	129925.	32481.	0.12	
Rep.tillage.cropping_system stratum					
Cropping_system	4	1809613.	452403.	14.16	<.001
Tillage.cropping_system	8	2902813.	362852.	11.36	<.001
Residual	24	766841.	31952.		
Total	44	6050873.			

Variate: Rice grain yield kg/ha Season III (Long Rain 2016).

Source of Variation	d.f.	s.s.	m.s.	v.r	Fpr.
Rep stratum	2	875.	437.	1.10	
Rep.tillage stratum					
Tillage	2	307596.	153798.	33.82	0.003
Residual	4	18191.	4548.	0.84	
Rep.tillage.cropping_system stratum					
Cropping_system	4	15995.	3999.	0.73	0.577
Tillage.cropping_system	8	176863.	22108.	4.06	0.004
Residual	24	130657.	5444.		
Total	44	650177.			