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RAINFED RICE-LEGUME BASED CROPPING SYSTEMS FOR SUSTAINABLE FOOD SECURITY AND SOIL FERTILITY IMPROVEMENT IN WESTERN KENYA

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ABSTRACT

Continuous increase in the world population, particularly in the eastern Africa region has increased the demand for food significantly. In view of this, the present system of sole cropping cannot meet the diversified needs of the small scale farmers. Field study of rainfed rice-legume based cropping systems was investigated and evaluated in western part of Kenya during the year 2011. The objectives of the study were: 1) to determine the effects of NERICA 11 rice/common bean (*KK8*) intercrop on yields of rice, 2) to determine the effect of rainfed rice/legumes (*Kenya kunde one*) intercrop on rice yield, 3) to monitor soil fertility dynamics associated with rainfed rice/legumes intercrop and to determine the economic viability of rice legume. Treatment combinations consisted of pure stand of NERICA rice, pure stand of beans and pure stand of cowpea , single row rice + single row of beans, single row rice + single row of cow pea, single row rice + double row of beans, single row rice + double row of cow pea, double row rice + single row of beans, double row rice + single row of beans, double row rice + single row of cow pea, double row of rice + double row of beans and double row of rice + double row of cow pea. Treatments were arranged in a Randomized Complete Block Design (RCBD) replicated 4 times. Results showed that, at a ratio of 1:1, single row of rice planted with single row of beans was significantly ($p \leq 0.05$) different from single row rice alternated with single row cow pea, while at a ratio of 1:2, single row rice alternated with double row beans and double cowpea were significantly ($p \leq 0.05$) different. However, double row rice against single rows of beans and single row cowpea were not significantly ($p \geq 0.05$) different. The biological efficiency of intercropping, measured in terms of Land Equivalent Ratio (*LERs*), at the ratio of 1:1 also showed that intercropping rain fed rice with cowpea has high compatibility factor of 1.84 and a derived intercrop benefit of 0.84 compared with bean intercrops (1.16) whose derived benefits was 0.16. Economic analysis results showed that double row rice alternating with single row cowpea gave the highest (KShs13787) net income with a corresponding low cost/benefit ratio of 0.25 compared with single row rice alternating with double row beans which gave low net income of (Ksh. 805.6) but had the highest cost-benefit ratio of 0.6. Thus farmers would be better of if they adopted double row rice alternating with single row cowpea spatial arrangement of intercrop. From the study, it was evident that NERICA 11 rice variety is compatible with both bean ***(KK8)*** and cowpea (*Kenya kunde one*).

Keywords: cropping system, soil fertility, food security, land equivalent ratio (*LERs*), economic results.

INTRODUCTION

Rice (*Oryza sativa*) is a major staple food crop in the tropics (George *et al*., 1992). Globally it is one of the most important food crops in the fight against hunger and ranked first in terms of consumption rate in Kenya (MOA-NARDSP, 2009).

Kenya is an agricultural country which has arid and semi arid tropical climate, favorable temperatures ranges and an extensive non irrigation system in Central, western coast and Nyanza provinces of Kenya which can translates into a large potential for raising two or more agricultural crops simultaneously. Small scale farmers constitute about 80% of the farming community in Kenya with their land sizes decreasing which suggest that the farming system involving intercropping is their only hope to ensure efficient utilization of their resources for increased production and family income (Abdul jabbar *et al*., 2010).

Rice cultivation was introduced in Kenya in 1907 from Asia (MOA 2009, NRDSP, 2009). It is currently the third most important cereal crop after maize and wheat (MOA, 2009, NRDSP, 2009). Being a staple food of the millions of people, it is the 4th source of income for people living in Nyanza and Eastern provinces after maize, sorghum and sugarcane. Hence its role in the economic development of Kenya cannot be overlooked. At present, rice is grown in an area of 16457 hectares in Kenya with a total annual production of 45256 tones giving an average yield of 3tones ha^{-1} (MOA, 2008). It is grown by small scale farmers as both cash and food crops. About 80% of rice grown in Kenya is from irrigated areas while the remaining 20% is produced under rain fed condition (MOA - NRDSP, 2009). In total, annual production of milled rice currently stands at 45-80 million metric tons per year (MOA -NRDSP, 2009). The annual consumption is increasing at the rate of 12% as compared to 4% for wheat and 1% for maize. This is attributed to progressive change in eating habit and its diversified utilization (MOA 2009, NRDSP, 2009). Unlike other cereals such as maize and wheat that are consumed by human beings and

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livestock feed, rice still remains the most favored human grain for consumption worldwide (Ito, 2002).

Continuous increase in population has triggered high demand for food tremendously in the recent past. This has necessitated expansion of non irrigated rice in the country. NERICA rice is a strain of hybrid rice that was originally developed by combining the hardiness of O*ryza glaberrima* (Resilient African rice species) with high productivity of the Asian species (*Oryza sativa*) through inter specific (WARDA 2000). The variety performs well in conditions suitable for grain legumes and cereals such as beans and maize respectively. Consequently, the need to integrate NERICA rice into the current cropping system that is dominated by maize, sorghum and finger millet among other crops in order to sustain food production and reduce poverty. Intercropping NERICA rice with legumes is a potential area that is yet to be exploited in Kenya.

Intercropping is one of the important cropping system in both sub and tropical Africa that has become popular among the small scale farmers as it offers the possibility of yield advantage for both component crops or one of them as compared to monocropping through improved yield and stability of yield (Nazir *et al*., 2002: Bhatti *et al*., 2006). Cropping system involving legumes and cereals together in the same field for multiple food production has been and is still is a popular practice among small scale farmers in the tropical countries (Ofori and Stern, 1987; Fujita *et al*., 1990).

Intercropping may be practiced for a number of goals and not just limited to just dry matter production in crop (Willey, 1979). This is due to the fact that even water use efficiency be increased by 18.99 % higher in intercropping than in sole cropping ((Morris and Garrity, 1993). Intercropping in rice (*Oryza sativa*) has been observed to reduce yield of rice (Chandra, *et al*., 1992; Saeed *et al*., 1999; Joshi, 2002). Improvement in soil fertility in a legumes-cereal intercrop involving wheat, cotton sesame and barley has been reported (Ahmad, 1990; Khan, 2000); Bhatti, 2005; Wahla, 2008). The residual soil P_2O_5 declined in all the cropping system compared to rice alone, because of extraction of insoluble soil phosphorus by legumes particularly (Balasubramaniyan and Palaniappan, 2001).

Several legume species are grown in the tropics as either sole-crops or as intercrops (Rachie and Roberts, 1974). The commonly used legumes for intercropping include groundnut, common beans (*Phaseolus vulgaris*) cowpeas (*Vigna unguiculata*) and Dolichos lab lab. The potential of growing legumes in association with major staple food crops like rain fed rice could be substantially enhanced through intercropping (Saeed, *et al*., 1999). This will help to improve and maintain fertility of soil (Patra and Catterjee, 1986), ensuring efficient utilization of nutrients (Ahmad and Saeed 1998; Maingi *et al*., 2001) and to ensure economic utilization of land and capital (Jeyabel and Kuppuswamy, 2001). It also allows efficient utilization of nutrients (Aggarwal *et al*., 1992; Nazir *et al*., 1997, Ahmad Saeed, 1998; Maingi *et al*., 2001) and ensuring economic utilization of land, labour and capital (Morris and Garrity, 1993; Singh *et al*., 1996; Jeyabel and Kuppuswamy, 2001).

Legumes used in crop production have traditionally enabled farmers to cope with soil erosion, declining levels of soil organic matter and available nitrogen (N) (Scott *et al*., 1987). Some farmers in developing countries who have adopted this low-input system have done so for socio-economic and climatic reasons (Okigbo and Greenland, 1976). Growing interests by farmers in intercropping system arises from an increasing awareness of environmental degradation, arising from high chemical inputs (Nielson and Mackenzie, 1977) and has given way to reduce modern agriculture's overdependence on commercial fertilizer. The yield advantage associated with intercropping as compared to sole cropping are often attributed to mutual complementary effects of component crops and would result into better total use of available soil resources. Although pure stand of legume produce better yields than intercropping systems, land productivity measured by Land Equivalent Ratio (*LERs*) and monetary gain clearly showed the advantages of intercropping of cereals with legumes (Mandal *et al*., 1990; West and Griffin, 1992). Thus one of the ways to increase seasonal production is to grow legume crops in association with cereals such as rain fed rice.

Upland rice-based cropping system is characterized by non flooding during most of the rice growing period. Upland rice farming comprises about 4% of world rice production (htp/irri. org/about-rice/rice). The current cropping system practiced by irrigated rice farmers in Kenya involves rotation of cereals and or legumes with rice. This is because it is not possible for these crops to grow in standing water. Initially there was no rice variety that could be grown under similar conditions like maize and sorghum. NERICA rice varieties perform in conditions similar to other cereals such as maize and sorghum. Consequently, the need to integrate NERICA rice into the systems dominated by maize, sorghum and finger millet in order to sustain food production and reduce poverty is considered a viable option. Moreover, during off season, the residues from these crops can help maintain animal health and milk production besides improving soil fertility (Wahla *et al*., 2009).

Rice beans and cow peas are important crops which can provide more economic return to farmers (Iqbabal *et al*., 2006; Ahmad *et al*., 2007). The areas under these crops cannot be increased as they face stiff competition for space from traditionally well known farmer's crop such as maize and sorghum. The success and adoption one or two patterns of cropping system would limit the extent at which rice farmers get exposed to environmental hazard such as water borne diseases (bilharzias). The present study was therefore initiated with the overall objective of developing sustainable and economically viable rice-based cropping systems. The specific objectives were: 1) to determine the effects of NERICA 11 rice/common bean (*KK8*) intercrop on yields of rice, 2) to determine the effect of rice/cowpeas (*Kenya*

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kunde one) intercrop on rice yield, 3) to monitor soil fertility dynamics associated with rice/legume intercrop and to determine the economic viability of rice legume.

MATERIALS AND METHODS

The study was conducted in two sites namely: Kibos (LM2) which receives annual mean precipitation of 1322 mm, mean maximum temperature of 30.8°C and mean minimum temperature of 16.4°C (KARI-Kibos Meteorological Weather Station, 2010). Busia Agricultural Training Centre (0, 20°N, 34°6E) is located at an altitude of 1220 m.a.s.l in the agro-ecological zone (LM1). It has shallow murram /medium) deep sandy clay soil (Rhodic Ferralsols) with bimodal type of rainfall, long rains coming to may while short rains are received from September to November and very erratic. The mean annual rainfall is 1690mm with potential evaporation of between 1800-2030m p.a. The mean temperature of the centre is 22.2°C with mean Minimum of 20°C and mean maximum of 28°C.

Soil samples were collected at the onset and end of the experiment. The samples were obtained from two distinct depths (0-15 and 15-30 cm) and analyzed for texture, p H, total N (%), Organic matter (O.M) and available P. Soil pH was determined with glass electrode (soil: water = 1:2:5) while soil texture was determined using particle size analysis. Available P was determined following procedure described by Olsen,and Sommers,(1982). Organic carbon was determined by Black wet oxidation method as described by Nelson and Sommers, (1982). Exchangeable bases were determined using ammonium acetate method (Black. 1957).

The test crops for this study were NERICA 11, common bean and cow pea. Treatments comprised of pure stand NERICA rice, pure stand beans, single row rice alternating with single row of beans, single row rice alternating with single row of cow pea, single row rice alternating with double row of beans, single row rice alternating with double row of cow pea, double row rice alternating with single row of beans, double row rice alternating with single row of beans, double row rice alternating with single row of cow pea, double row of rice alternating with double row of beans and double row of rice alternating with double row of cow pea.

Seedbed was prepared to a finer tilth to allow uniform crop establishment. Planting was done by hand with application of basal fertilizer (TSP) at 75 $P_2O_5ha^{-1.}$ The crops were top dressed in two equal splits at tillering and boot stage respectively with CAN at equivalent rate of 37.5 kg N ha^{-1} per split.

Rice seeds were planted at a spacing of 30cm by drill at the rate of 75kg ha^{-1} in pure stand, while seeds of common bean were planted at the rate of 30kg ha^{-1} at a spacing of 50cm by 15cm in pure. Cow pea seeds were planted at the rate of 25kg ha^{-1} at the spacing of 60 cm by 15cm in pure stand. The space between any rice row and any of the legume rows was 30cm apart. Plots measuring 6 by 1.8 m was maintained for all treatments or plots. The common beans were harvested first at two and half months followed by cow pea at three months, while rice was the last to be harvested at four months after planting.

The experiment was arranged in a Randomized Complete Design (RCBD) and replicated four times. The statistical model (Gomez and Gomez, 1984) used was:

$$Y_{ÿklm} = \mu + E_i + \beta_j + C_k + C\ E_{i\ k} + \epsilon_{ijklm}$$

Where

$Y_{ÿklm}$= Observations, μ = Grand mean, E_i = ith Environment, βj = Effect of block in the i^{th} environment, Ck = Effect of cropping system in the j^{th} block in the i^{th} environment, $Єi_{\ jklm}$= the error term.

The data collected included soil pH, NPK, emergence count of both crops, seedling number of fertile tillers, Kernel per panicles, grain yield of crops components, harvesting index and 1000 Kernel weight, of rice crops.

Biological efficiency indices

Land Equivalent Ratio *(LER)* was calculated using the formula:

La + Lb = Ya/Sa + Yb/Sb (IRRI, 1974)

Where

La and Lb are the LER for the individual crops, Ya and Yb are the individual crop yields in intercropping, and Sa and Sb are their yields as sole crops.

Area-time equivalency ratio *(ATER)*

Since land equivalent ratio does not take into account the time for which land is occupied by the component crops of an intercropping system, Area Equivalency Ratio (*ATER*) was also determined. It considers the intensification in both time and space. This is because; crop production is not solely a function of land area, crop management and environment alone as implied by *LER*. It is also related to the duration of crop growth or time during land is occupied by each crop (Leihner, 1983; Hiebsch and McCollum, 1987; SusanAnna John, 2005; Seran and Brintha, 2009) and was calculated as indicated below:

$$ATER = \frac{Ry_a \times t_a) + Ry_b \times t_b)}{T}$$

Where're = Relative yield of species a' or b', i.e., yield of intercrop yield of main crop, t = duration (days) for species a' or b' and T = duration (days) of the intercropping system.
Where Y_{ab} and Y_{ba} are the individual crop yields in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop. Z_{ab} and Z_{ba} were proportion of land area occupied on intercropping when compared to sole crop for species a` and b` respectively (Mc Gilchrist, 1965).

Analysis of economic indices

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Economic analysis involved collection of data on prices and quantities of inputs used. The inputs used included rice seed, fertilizer, labour and insecticides. The output and inputs were valued at market prices. The results were used to compute net income, Cost benefit ratio and rice grain yield equivalent s of intercrop. Net income was computed as the difference between management (Family labour and operator's) cost and gross margin. Cost benefit ratio was computed as gross return divided by total variable cost of cultivation:

Cost-benefit Ratio= Gross return divide by Total (variable) cost of cultivation
Rice grain yield equivalent of intercrop (RGYE) was computed as yield of intercrop divided by market price of rice and multiplied by market price of Intercrop (Beans):
Rice equivalent yield kgha^{-1} = (Yield of intercrop divide by market price of rice) × Market price of intercrop

The yield of rice and bean intercrop was converted into rice grain equivalent on the basis of existing market price of each crop (Anjeneyubu *et al*., 1982).

The parameters recorded were analyzed using the standard procedures of SAS (2003) statistical package. The differences between means were compared by Least Significant Difference (LSD) test at p = 0.05 using the General Linear Model (GLM).

RESULTS AND DISCUSSIONS

Rainfall data of KARI-Kibos and Busia ATC

Moisture is a very important factor in plant growth and development. In February the amount of rain received in Kibos was about 10mm compared to Busia (20mm) Figure-1. The mean rainfall amounts was very low in KARI-Kibos as compared to Busia which had adequate rainfall between March and May except in June. Rainfall was distribution at Busia throughout the crop growth and development was better than in KARI-Kibos. The Figures show that it was possible to have two crop planting season at Busia than KARI- Kibos (Figure-1).

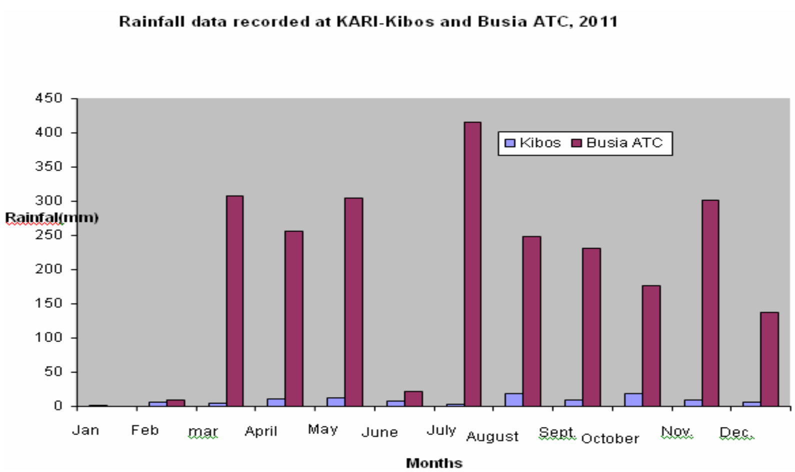

Figure-1. Rainfall received at KARI-Kibos and Busia ATC in, 2011.

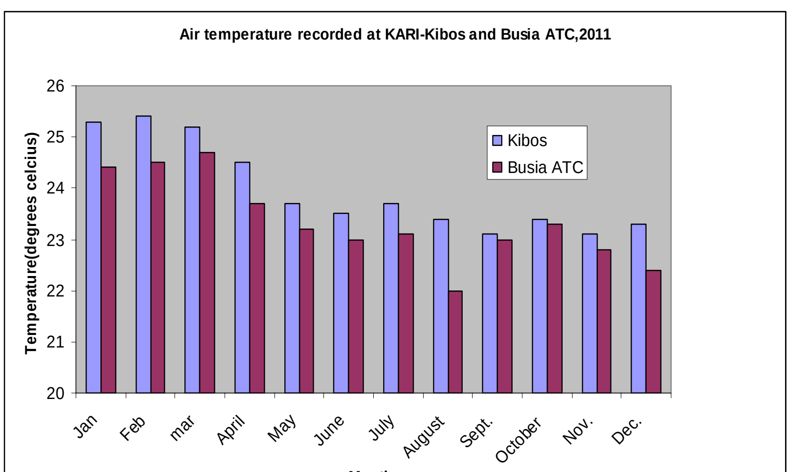

Fig.2:Temperature received at KARI-Kibos and Busia ATC

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Air temperature recorded at KARI-Kibos and Busia ATC

Temperature usually contributes economically towards the crop growth, development and productivity up to harvesting maturity stage of a crop. This is because the change from the vegetative stage of a crop to the reproductive phase may be influenced by temperature changes. Significant temperature differences between the two sites were between January and July. Between September and November both sites experienced almost the same temperature (Figure-2).

Soil characterization

Kibos soil is moderately acidic (pH 6.5) while soils in Busia ATC fall within the bracket of acid to strongly acid soil. The site has a mean pH of 4.3 (top soil) and o 3.4 in the sub soil (Table-1). Total nitrogen was generally low at Kibos and Busia sites. There was, however, high nitrogen concentration in the sub soil compared to the top soil, a trend that was attributed to accumulation of N through leaching. There was adequate supply of exchangeable cations across sites.

Table-1. Some selected soil properties at KARI- Kibos and Busia ATC.

Sample reference	pH (W)	Organic Matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (ppm)	Exchangeable Ca (ppm)	Exchangeable Mg (ppm)	% Sand	% Clay	% Silt	Textural Class
Kibos topsoil at planting	6.37	3.03	1.3141	28.21	450.4	4292	220.7	50	24	26	Clay loam
Kibos subsoil at planting	6.56	3.10	0.2591	29.41	354.6	2125	175.5	52	22	26	Sandy clay loam
Kibos topsoil at harvest	6.67	2.48	0.2913	27.52	212.7	779	198.1	58	20	22	Sandy clay loam
Kibos subsoil at harvest	6.6	3.16	0.0906	12.48	581.6	1988	213.9	52	22	26	Sandy clay loam
Busia topsoil at harvest	5.6	4.30	0.1703	52.91	46.8	2899	244.5	48	24	28	Sandy clay loam
Busia subsoil at harvest	5.51	3.44	0.0902	16.58	55.3	1174	262.6	42	28	30	Sandy clay loam

Effects of cropping system on grain, biomass, fertile tillers, and kernel per panicle of rain fed rice in two locations

Rice yield

The grain yield is the main and ultimate objective of growing rice crop in an intercrop. The yield factor is related to many factors such as plant population, 1000 grain weight, number of tillers, number of kernels per panicle and agronomic practices employed during crop development. So any failure or success of the above mentioned factors will affect the rice grain. The result showed the sole crop yielded more than the intercropping systems. However intercropping rainfed rice with legumes (Table-2) significantly ($p \leq 0.05$) reduced the grain of rice yield ha^{-1}. Cow peas caused significant ($p \leq 0.05$) yield reduction in grain rice of associated rice crop when compared to sole crop. The significant yield reduction ($p \leq 0.05$) was also observed in rice and common bean intercrop. The intercropping patterns involving rice and legumes showed no significant difference ($p \geq 0.05$) between them (Table-2) and were at statistically at par while single rows of rice alternating with double rows of beans caused least reduction in grain yield of rice.

The reduction in grain yield could be attributed to probably due to significant less number of fertile tillers $perm^2$, kernels per panicle; 1000kernl weight in all the intercropping patterns (Saeed *et al*., 1999) and extended drought during tillering stage and grain filling period which are very critical sages directly related to the grain yield (Figures 1 and 2) or due to probably inter and intra competition for moisture, light space and nutrients. The results also showed that the sole cropping yield, pure rice stand (2.375), pure bean stand (1.150), pure stand cow pea (1.425) had high value more than their intercrop counterpart (Table-2). However some of the intercrop or patterns which increased grain yield of rice in the experiment significantly could be attributed to nitrogen fixing ability of the two legumes (cow pea and common beans) and extensive root system of cereal in this case the rainfed rice (Chen *et al*., 2004). The reduced yield of rice in intercrop could have also been associated with inter-specific interaction competition both above and below the ground between components crop for light, water, nutrients and air and the depressive effect of vegetative growth habit of the two legumes. This similar observation has also been reported by (Pal *et al*., 1992) who reported the suppressive effect of sorghum in sorghum and soybean

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intercrop. Similar observation has also been made by (Muoneke *et al*., 2007) who narrated that there was yield reduction in soy bean intercropped with maize and sorghum. In other reports related to intercropping, it has also been observed that intercropping pea with mustard reduced the yield of mustard (Banik *et al*., 2006).

Harvest index

Harvest index is used to determine the efficiency by which a crop converts the dry matter into the economic yield. The shorter the variety the higher the index value (Gopal, 1990). The more the value of the harvest index of a crop or a variety the more is the efficiency of the crop to convert the dry matter into the economic part (grain or forage) depending on the objective one wants to achieve. The data showing the harvest index of rice crop is shown in Table-1. The table shows that intercropping rain fed rice had significant effect on the harvest index. Higher value of harvest index (0.895) (Table-2) was obtained when single row rainfed rice was intercropped with single row cow pea than on a pure basis. The least harvest index (0.193) (Table-2) was obtained when ringlet row rainfed rice was intercropped with double row bean. As far as the data is concerned harvest index had significant effect on the cropping patterns involving rainfed rice and legumes as shown in Table-2 where pure stand of rain rice was 0.383, while the intercrop was 0.893 with cow pea. The results concur with the results of (Saleem *et al*., 2003) who found significant effect of planting patterns on harvest index in sunflower and mungbean. The results also in line with Sultana (2007) who also found significant effect of intercropping sunflower and green gram on harvest index. The same above observation was also narrated by Batt (2005) on the significant of intercropping and planting patterns on harvest index of green gram.

Table-2. Effects of cropping system on biological yield and yield components.

Treatments	**Rice yields** ($Kgha^{-1}$) **grain**	**biomass**	**Tillers** (m^2)	**Kernel per panicle**	**1000seed weight** (g)
Pure stand of rice	2199a	8278a*	259.89a	162.0a	22.16a
Pure stand of beans	1065bcd	2176cd	245.51b	153.7b	375.78b
Pure stand of cow pea	1315b	3356bcd	226.92c	142.7c	129.98c
Single row rice + single row bean	602de	3407cd	239.31b	150.3b	21.35b
Single row rice + single row cow pea	986bcde	3588bc	237.12b	150.0b	22.25b
Single row rice + double row beans	1213e	1679d	237.12b	149.1b	22.625b
Single row rice + double row cow pea	753cde	2142cd	239.64b	149.0b	21.189b
Double row rice + single row bean	1042bcd	4514b	239.87b	148.6b	21.425b
Double row rice + single row cow pea	1134bc	3646bc	244.79b	149.0b	22.488b
Double row rice + double row beans	637dce	2431dc	241.40b	149.0b	20.625b
Double row rice + double row cow pea	694dce	2489cd	238.06b	148.5b	21.775b

Mean of replications. Mean separation in column Duncan Multiple Range Test (DMRT) at 5% level

1000 grain weight

1000 grain weight is one of the important factors contributing to overall yield of the rainfed rice grain. The data related to 1000 grain weight is shown in Table-2. The Table shows significant effect of different intercropping patterns involving rainfed rice with legumes (common beans and cow peas) on 1000 grain weight. The higher value of 1000-grain weight was obtained (22.625g) when single rice was alternating with double row of beans higher than the pure stand of rainfed rice. The result concurs with Sahi (1988) which showed significant effect of intercropping lentil and wheat on lentil 1000-grain weight. The 1000-grain weight was decreased significant by almost all intercropping patterns and intercropping probably due to competitive effects of the respective components crops (Khan, 2001) who also reported similar suppressive effects of intercropping wheat and legumes on 1000-grain weight of wheat.

Biomass

The effect of intercropping and patterns on biomass of rainfed rice area shown (Table-2) which showed that all intercropping involving rain fed rice caused significant differences and reduction in rice biomass. Maximum rainfed rice biomass was obtained from double row rainfed rice intercropped with single row of (bean 4.875)., while the minimum biomass of rainfed rice was observed in an intercrop involving single row rice plus double row beans (1.181kg). Low biomass yield value of rice intercropped with particularly where single row rainfed rice was intercropped with double rows of beans was probably due to less vegetative growth of rainfed rice in the treatment because of stiff competition

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between associated crops. Similar observation was also made in rice yield (Saeed *et al*., 1996). The highest biomass yield of rice was as a result on rice + cow pea followed by that of common bean which were not statistically significant different. However high turn out of biomass (4.875) was observed in double rows of rice intercropped with single row of beans (Table-2). The low yield/ha in biological value of the rice crop could be due vegetative growth of the two types of legumes, mainly common bean and cow peas of offering severe competition between the components crop for nutrients and water. Reduced biomass yield of wheat by different intercrop has also been narrated by Tarreen *et al*., (1988).

Effect of intercropping rainfed rice with beans and cowpea on biological efficiencies indices

Land equivalent ratio (*LERs*)

All intercropping systems resulted in yield advantages and all the components were compatible with one another. This is reflected in (Table-3) with greater ratio of Land Equivalent Ration (*LERs*) of 1.16 (rice and beans) and 1.84 (rice + cow pea) with an intercrop benefit of 0.16 and 0.84, respectively. This demonstrates the yield advantages for the intercropping plots. In particularly rice and cow pea gave the highest *LER* of 2.52 and 2.91 implying over 80% of land would be required as sole crop to produce the yield of obtained under intercropping system. These results are in agreement with that of Saeed (1999), who also reported that intercropping legumes with cereals gave more rice yield than sole cropping. The higher *LERs* (Table-3) of rain fed rice at almost cow pea and bean densities showed that rainfed rice was more competitive than cow pea and beans and that rice utilized the N fixed by both cow pea and common beans for better growth, development and yields. Total *LER* values were higher in all the intercrops than one indicating the advantage of intercropping over sole stands in regard to use of environmental sources for plant growth (Mead and Willey, 1980). This similar case has also been reported where pea was intercropped with barley (Li *et al*., 1999). The total *LERs* values also showed that, compared to bean/rice intercrop *LER* of cow pea appeared to have more beneficial land use efficiency in almost all intercrop patterns. In conclusion rain fed rice benefited from residual nitrogen fixed by the cow pea and common beans. This is an indication that three crops are also compatible as their growth stages for competition for growth factors do not overlap.

Table-3. Effect of intercropping rainfed rice with beans and cow pea on biological efficiency indices.

Treatments	Yields (component crops)/ha	*LERs*	Total *LERs*	Intercrop benefit	*ATER*	Aggressivity
Pure stand of rice	2199a	-				-1.64
Pure stand of beans	1065bcd	-				-0.086
Pure stand of cow pea	1315b	-				-0.806
Single row rice +single row bean	602de	0.27+0.89	1.16c	0.16	1.278	0.215
Single row rice + single row cow pea	986bcde	0.448+1.39	1.84a	0.84	1.186	-1.446
Single row rice + double row beans	1213e	1.09+0.47	1.56b	0.56	1.09	0.482
Single row rice + double row cow pea	753cde	0.84+0.34	1.18c	0.18	1.246	-2.6
Double row rice + single row bean	1042bcd	0.59+0.47	1.06c	0.06	1.393	-2.89
Double row rice + single row cow pea	1134bc	0.512+0.78	1.29c	0.29	1.44	-
Double row rice + double row beans	637dce	0.92+0.29	1.21c	0.21	1.397	-1.64
Double row rice + double row cow pea	694dce	0.32+0.76	1.07c	0.07	1.263	-0.086
F test	2199a		*	*	NS	-0.806

Means followed by the same letters in each column are not significantly different according to DMRT at 5%

Area time equivalent ratio (ATER)

The *ATER* usually gives a more realistic comparison of the yield advantage of intercropping over the sole cropping than LER as it considers variation in duration taken by the components crops. In all the treatments except the pure stand all *ATER* values were smaller than the *LER* values (Table-3) indicating the over estimation of resources utilization in the LER. The results showed that there were no significant differences in *ATER* among the treatment. It was high where double row rice was intercropped with single row cow pea (1.44). This suggests that all the treatments performed well in *ATER*. A higher value of *ATER* is usually attributed to efficient utilization of land, water, light and nutrient. When there is a substantial difference between growth duration of associated crops time factor becomes an important element and Area Time Equivalent Ratio is compared to be a more appropriate index of efficient of the system (Ofori and

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Stern, 1987). Area time Equivalent Ratio (*ATER*) seemed to follow similar trend to that of Land Equivalent Ratio (*LER*). This is in line with the findings of Okori and Stem (1987). The generally higher value of *ATER* in intercrop component compared to sole cropping may be attributed to efficient utilization of land resources, added fertilizer and light utilization. When the difference between growth duration of component crops are substantial time between growths durations of component crops are substantial time becomes an important in *ATER* is considered to be more appropriate index of efficient of the system (Ofori and Stern, 1987).

Negative aggressivity values obtained for almost treatment signified that cow pea and beans were dominated by rice (Table 3). This may due to be different in growth habits of the three associated crops. This also implies that aggressivity values were significantly influenced by the intercrop and spacing. The results does not concur with the findings according in which rapeseed was dominant, having positive aggressivity value when grown in association with wheat (Ali, 1999) and linseed (Shahid and Saeed, 1997) Based on the results (Tables 2 and 3) cow pea can be suggested and promoted as a promising future intercrop component for rice.

Economic benefits

Double row rice alternating with single row cow pea gave the highest (13787) (Table-4) net income with a corresponding low cost/benefit ratio (C/B) of 0.25 (Table-3). This contrasts with single row rice alternating with double row beans which gave low net income of 805.6 but had the highest C/B ratio of 0.6. Single row rice+ single row cow pea gave the second highest net benefit of 9139 but ironically it also gave the lowest C/B ratio of 0.02 (Table-4). Three treatments: single row rice +single row bean, single row rice + double row cow pea and double row rice+ single row bean gave negative net incomes. From these results it is evident that farmers would be better of if they adopted double row rice alternating with single row cow pea spatial intercrop pattern though it has lower C/B) compared to single row rice alternating with double row beans spatial intercrop pattern that gave low net income but had the highest C/B ratio.

Table 4. The effect of intercropping rain fed rice with legumes on economic analysis indices.

Treatments	Rice grain kg/ha	*RYE	Revenue	Total variable cost	Net income	Benefit-cost ratio*
Pure stand of rice	2199		53240	42250	1731.450	0.04
Pure stand of beans	1065		42592.59	19250	23342.59	1.20
Pure stand of cow pea	1315		52777.59	19250	33527.75	1.74
Single row rice + single row bean	602	1.09	49074.07	54750	-5675.93	0.10
Single row rice + single row cow pea	986	0.86	45611.10	54750	9138.89	0.17
Single row rice + double row beans	1213	1.22	53944.40	54750	805.556	0.60
Single row rice + double row cow pea	753	1.53	80796.30	54750	-2646.3	0.48
Double row rice + single row bean	1042	1.15	53240.70	54750	-1509.26	0.03
Double row rice + single row cow pea	1134	1.29	68537.0	54750	13787.04	0.25
Double row rice + double row beans	637	1.38	55814.80	54750	1064.815	0.02
Double row rice + double row cow pea	694	1.57	79407.41	54750	2465.41	0.50

***RYE=** Rice Yield Equivalent

CONCLUSIONS

a) The result showed the two types of legumes were compatible with rainfed rice as reflected in LER
b) Intercropping cow pea with rice gave higher yield of rice grain and biomass than rice bean intercrop.
c) The number of kernel per panicle did not differ significantly among the rice in the intercrop.
d) Rainfed rice can perform well when intercropped with cow pea than common bean.
e) The result showed that both cow pea and beans were dominated by rice.

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