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Original article

Rice (*Oryza Sativa*) and chickpea (*Cicer Aritinum L*) relay intercropping systems in an additive series experiment in rain fed lowland ecosystem of fogera vertisols

Y. Bitew*, F. Asargew

Agronomist, Adet Agricultural Research Centre, Amhara Agricultural Research Institute, P .O. Box 08, Bahir Dare, Ethiopia

*Corresponding author; Agronomist, Adet Agricultural Research Centre, Amhara Agricultural Research Institute, P .O. Box 08, Bahir Dare, Ethiopia

ARTICLE INFO

ABSTRACT

Article history,

Received 17 December 2014

Accepted 25 January 2015

Available online 28 January 2015

Keywords,

Rice

Chickpea

Relay intercropping

Study on rice as a main crop-chickpea as a companion crop relay intercropping in an additive series experiment in rain fed lowland ecosystem of Fogera vertisols was conducted for two consecutive years to test the rice-chick pea relay intercropping planting method and to determine the optimum proportion for component crops in rice- chick pea relay intercropping on transplanted rice. The experiment was conducted in randomized block design with three replications. Five seed rates of chick pea relay intercropped in between rows of transplanted rice and one sole rice were tested i.e. full recommended seed rate of chick pea relay intercropped in between rows of transplanted rice, two-third of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice, two-third of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice, half of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice, half of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice and the sole transplanted rice used as comparison. Rice yield and yield component data were statistically subjected to analysis of variance using SAS-JMP-5 software. All growth, yield and yield component of rice did not

significantly affected by additive relay intercropping and seed proportion in rice-chickpea relay intercropping systems. However, the study conducted for two consecutive years at all test sites confirmed that chick pea after twenty days from the planting time was completely dried and unable to give seed yield from rice-chickpea relay intercropping experiment. Hence, under current crop management practice of rice at Fogera vertisol areas, relay intercropping of chickpea with rice is not economically important for farmers.

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1. Introduction

Relay cropping system refers to growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest (Francis, 1986). A greater stability of yield over different seasons could be derived through the use of relay cropping. Because the lower period competition, relay cropping generally can provide higher relative yield totals than mixed or row intercropping (Sanchez et al., 1985). Relay planting is practiced primarily to gain time for multiple cropping, to plant the subsequent crops at their optimum planting date when the current crop harvest is delayed (Reddy and Willey, 1981), to avoid moisture stress in the post rainy season crops, to avoid labor peaks at better control of soil erosions, improvement in human nutrition, and crop residue quality for feed and risk aversion in case of failure of one crop.

On the other side, a monoculture is the agricultural practice of producing or growing a single crop or plant species over a wide area and for a large number of consecutive years. Monocultures can lead to the quicker spread of pests and diseases, where a uniform crop is susceptible to a pathogen (Zhu, 2000).

Rice, the most important cereal in the world, and chickpea (*Cicer arietinum L.*), the third most important pulse crop plays a vital role in global agricultural economy (Central statistical agency, 2013). Rice is one of the important staple foods and its production area has been increasing year after year in Fogera and Lebokemekem areas (Central statistical agency, 2013). Fogera plain contributes 32 % of rice production in the country (Ethiopian Institute of Agricultural Research, 2011). Farmers in Fogera plain use dry seed broadcast planting method for rice production (Tilahun et al., 2008). It is the main crop that has been produced mainly in mono-cropping systems for many years in Fogera and Lebokemekem areas. Rice and sugarcane are two crops that have been produced in mono-cropping systems for many years in the tropics (Zhu, 2000). Recently, farmers in Fogera and Lebokemekem areas practiced traditional rice as a main crop-grass pea as a companion crop relay intercropping planting method to increase yield per unit area. However, management of rice-relay intercropped with legume to maximize crop production follows simple natural principles, and its practice is limited only by the rice-grass pea relay cropping system. Moreover, grass pea is a low price crop in the region and hence it is very economical to replace grass pea with chick pea. Though, rice-chick pea relay intercropping planting method is not practiced in rice producing areas of the country, it is essential to test this practice at farmers' field. Therefore, the objective of this experiment were to test the rice-chick pea relay intercropping planting method and to determine the optimum proportion for component crops in rice- chick pea relay intercropping on transplanted rice.

2. Materials and methods

The experiment was conducted in rain fed lowland ecosystem in Fogera vertisols at three sites for two consecutive main cropping seasons (2011-2012). Fogera is situated 60 km North-East of Bahir Dar Town, South Gonder, Amhara Region. The experimental site is located at Latitude 13° 19' and Longitude 37° 03' and on an altitude of 1815 m.a.s.l. The monthly temperature and rainfall for the experimental site are indicated in Figure 1 and 2. The average climatic data of Woreta shows that the mean annual minimum temperature is 11.5 °C and the mean annual maximum temperature is 27.89°C and the annual mean temperature nearly 18.3 °C. As indicated in

Figure 2 rainfall of the area is uni-modal, usually occurring during June to October, and average annual rainfall reached to 1300 mm (Heluf and Mulugeta, 2006). According to (Mulugeta, 2000), the soil on which the field experiment was conducted is classified as Pellic Vertisol. Analysis of composite surface soil samples collected from the experimental field indicated that the soil is moderately acidic (pH in 1:1 soil: water ratio of 5.6) and clayey (71.3% clay). The surface soil was high in total N (0.28%), organic carbon (3.0%), percent base saturation (79.4%), cation exchange capacity (52.9 cmolc kg⁻¹) and in Olsen extractable available P (36.2 mg l⁻¹), and medium (265.2 mg l⁻¹) in available K contents (Mulugeta, 2000).

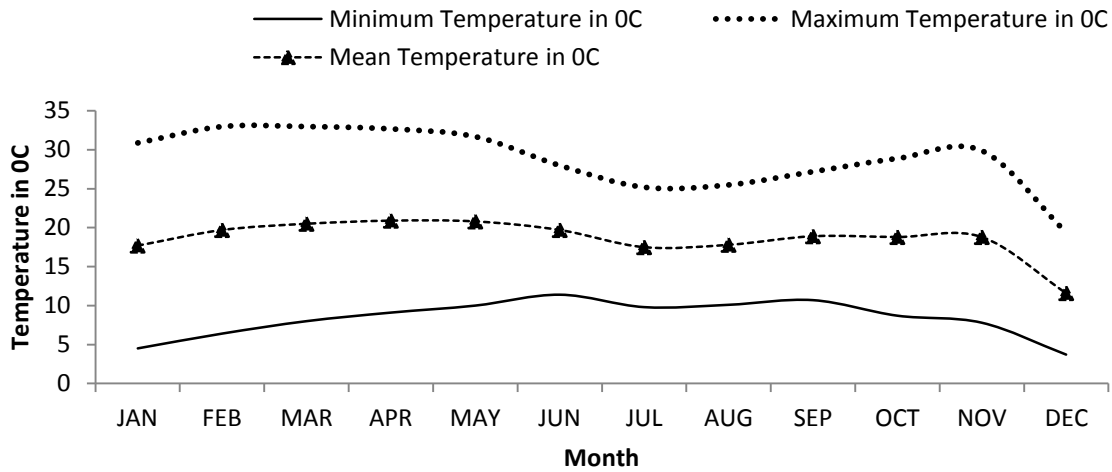


Fig. 1. Minimum, maximum and mean temperature (°C) pattern at fogera district.

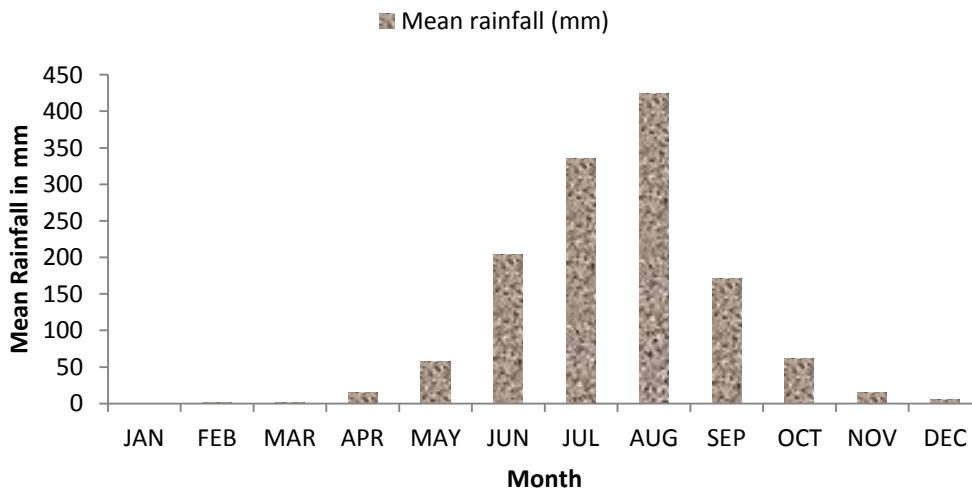


Fig. 2. Rain fall (mm) pattern at fogera district.

The experiment was conducted in randomized block design with three replications. Five seed rates of chick pea (Shasho) relayed intercropped in between rows of transplanted rice (X-Jigena) and one sole rice were tested i.e.:

1. T1=Full recommended seed rate of chick pea relay intercropped in between rows of transplanted rice
2. T2=Two-third of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice
3. T3=Two-third of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice

4. T4=Half of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice
5. T5=Half of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice).
6. T6=The sole transplanted rice used as comparison.

Rice seedling preparation was conducted as per the recommendation package prepared by Adet research center. At the time of transplanting, three seedlings were planted on a hill at a depth of 3cm. The distance between hills within the row and between the rows was 20 cm and 25 cm, respectively. Chick pea was relay intercropped in broad-casting in between rows of rice at the time of appropriate moisture level. Plot size of 5m length and 4m width was used. Rice and chickpea were planted at a depth of 4 cm, 3 cm, respectively. For, those crops 80 kg/ha and 75 kg/ha seed rate were used, respectively. DAP (30kg/ha for rice and 100kg/ha for chickpea) and UREA (50kg/ha for only rice) were used. All DAP and half UREA was used at planting and the remaining UREA was applied at tillering of rice.

2.1. Data collection and analysis

All appropriate rice growth, yield and yield component (Number of tillers/ m², Grain yield (kg/ha), Number of Fertile panicles/ m², Plant height (cm), 1000 kernel wt.(g)) were collected. Regarding the chickpea growth, yield and yield component, only data on crop stand at emergency and before dried were collected because chickpea was completely dried and impossible to get other agronomic attributes. Only rice yield and yield component data were statistically subjected to analysis of variance (ANOVA) using (SAS, 2002) software. Combined analysis of variance for rice was performed over years and sits.

3. Results and discussions

3.1. Rice growth, yield and yield component

Study on rice-chickpea relay intercropping in an additive series experiment in rain fed lowland ecosystem of Fogera vertisols are presented in this paper. Results of combined analysis of variance across years showed that all growth, yield and yield component of rice (Number of tillers/ m², Grain yield (kg/ha), Number of Fertile panicles/ m², Plant height (cm), 1000 kernel wt.(g)) did not significantly affected ($P>0.05$) by rice-chickpea relay intercropping systems and seed proportion (seeding ratio) (Table 1). This experiment gave an average yield of 4499-4624 kg/ha (Table 1). This might be due to early planting of rice in relay intercropping system takes advantage in peak resource demands for nutrients, water, and sunlight for all treatments. Similarly (Preston, 2003) and (Bantie et al., 2014) reported that intercropping crops that have feature staggered planting and maturity dates or development periods takes advantage of variations in peak resource demands for nutrients, water, and sunlight. Selecting crops with different planting and maturity dates (lupine and finger millet) can also assist staggered harvesting and separation of grain commodities (Yayeh, 2014). Moreover, even though, resource competition between two crops planted in relay cropping system is very low (Muhammad and Abdul, 2005), the present study showed that rice grain yield had not different in all treatments (planted in different seeding ratios or seed proportions) probably due to complete failure of chickpea at mid developmental stage during rice-chickpea relay intercropping system.

3.2. Chickpea growth, yield and yield component

The effect of rice-chickpea relay intercropping on the yield and yield component of rice and was studied in depth for two years at three sites per location in high rice production potential areas of Ethiopia (Fogera). The results of an experiment for two consecutive years at all test sits confirmed that chick pea was fully emerged and showed normal growth for 15 days from the planting time. However, after fifteen days from the planting time chickpea plant population at all plots, sites and in both years were wilted. Nearly, after twenty days from the planting time the crop was completely dried and unable to generate any data (yield and yield component of chickpea) from rice-chickpea relay intercropping experiment. This is not due to diseases and insect pest damaged but it might be due to three main important reasons: problem of plant architecture, narrow plant spacing (mainly row spacing) and extremely high temperature in the area.

Table 1

Results of analysis of variance for the two years combined effect of rice-chickpea relay intercropping on rice growth, yield and yield components (2011-2012).

Treatments and statistics	Grain yield (kg/ha)	Number of tillers/ hill of rice	Number of fertile panicles/ hill of rice	Plant height (cm) of rice	Thousand seeds weight (g) of rice
T1	4499	8.64	132	90.5	25.82
T2	4529	6.91	129	88.32	25.57
T3	4618	6.55	131	91.71	25.93
T4	4624	7.62	127	89.36	25.58
T5	4622	8.39	133	89.51	25.39
T6	4541	7.66	133	86.8	25.48
Mean	4572.17	7.63	130.83	89.37	25.63
LSD (5%)	NS	NS	NS	NS	NS
CV%	13.4	17.2	12.5	6.7	3.5

Notes: Values (means) not connected by different superscript letters are not significantly ($P>0.05$) different within columns according to Tukey-HSD tests. T1=Full recommended seed rate of chick pea relay intercropped in between rows of transplanted rice; T2=Two-third of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice; T3=Two-third of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice; T4=Half of the recommended seed rate of chick pea relay intercropped in between rows of transplanted rice; T5=Half of the recommended seed rate of chick pea relay intercropped in between alternate rows of transplanted rice and T6=The sole transplanted rice used as comparison.

3.2.1. Plant architecture

When designing an intercropping scheme, there are four components to consider: spatial arrangement, plant density, maturity date and plant architecture. Plant architecture is a commonly used strategy to allow one member of the mix to capture sunlight that would not otherwise be available to the others. Increased yields of some crops have resulted from indirect selection of plant architectural traits related to yield. Widely spaced corn plants growing above an under storey of beans and pumpkins is a classic example (Preston, 2003). More efficient use of light can be attained by careful spatial arrangements of multi-storey cropping with tall and short crops, provided the short crops are adapted to low light intensities. In the present experiment, chickpea was planted nearly when rice was at maturity stage. However, chickpea produced no seed in an intercrop with rice due to its failure to grow and flower in the shade of a full rice canopy. Similar study in different crops done by (Jones and McCown, 1983) who reported that Caribbean stylo (*Stylosanthes hamata* cv. Verano) produced little seed in an intercrop with maize due to its failure to flower in the shade of a full maize canopy.. This study examines the potential relationship between plant architecture and yield for a legume grown under intercropping (Nelson, 2006).

3.2.2. Row spacing

The other most important reason why chickpea was completely failed is that transplanted rice was planted in 20 cm between hills with in rows and 25 cm between rows which is very narrow to conduct management practices for chickpea. Relay cropping is not possible under the present method of planting rice in 20 x 20 cm hills because of narrow row spacing on one hand and intensive binding up of the soil by root mass of closely growing rice plants on the other (Arshad et al., 2003). The results of Arshad et al., 2003) further led to the conclusion that rice should preferably be planted in 60 cm apart triple row strips as it not only facilitates relay cropping but also gives total yield/ha comparable to the conventional planting system in 20 x 20 cm/hills which does not permit management practices and easy planting of relay crops.

3.2.3. Extremely high temperature

Chickpea is one of the essential semi-arid tropical legume crops (Devasirvatham et al., 2003). In Ethiopia it is mainly grown during the post-rainy season on stored soil moisture; in this instance the crop is exposed to terminal drought which is accompanied by rising temperatures. Recent climate data from field experiments in Fogera plain during sowing and growth time after the rainy season (end of September to January) showed a mean temperature

of 28 °C (Figure 2). Sowing temperature is an important determinant of yield, and will become a significant constraint should predicted climate change lead to higher future sowing temperatures. Likewise, Berger and Turner (2007) reported that chickpea may also experience high temperatures in the seedling phase if planted early. Moreover, according to (Basu et al., 2009) and (Gaur et al., 2007) reported by chickpea productivity is constrained by several abiotic stresses and temperature is one of the most important determinants of crop growth over a range of environments. Study conducted by (Ellis et al., 1989) indicated that the optimal temperature for germination of chickpea is 10 -15 °C and noted that a high germination temperature the mobilization of cotyledon reserves and embryo growth are adversely affected. Low photosynthetic rates and high transpiration rates occur during high temperature stress and tend to reduce plant establishment in chickpea (Singh and Dhaliwal, 1972). Similarly, (Sanjeev et al., 2013) investigated that the pollen viability, pollen germination, tube growth, pollen load and stigma receptivity decreased with increases in temperatures to 45/35°C. The sensitive genotypes were not able to set any pods at 45/35°C, whereas the tolerant genotypes produced only few fertile pods at this temperature. It was concluded that heat stress leads to loss of pollen as well as stigma function and induces oxidative stress in the leaves that cause failure of fertilization and damage to the leaves, respectively.

4. Conclusion

The present study showed that all growth, yield and yield component of rice did not significantly affected by additive relay intercropping and seed proportion in rice-chickpea relay intercropping systems. This might be due to early planting of rice in relay intercropping system takes advantage in peak resource demands for nutrients, water, and sunlight for all treatments. However, the results of an experiment for two consecutive years at all test sites confirmed that chick pea after twenty days from the planting time was completely dried and unable to get seed yield from rice-chickpea relay intercropping experiment probably due to problem of plant architecture, very narrow plant spacing and extremely high temperature during crop growth. Hence, under current crop management practice of rice at Fogera and Libokemkem areas, relay intercropping of chickpea with rice is not economically important for farmers.

Research needs

At Fogera vertisols, relay intercropping of rice with grass pea in additive series in which rice is the main crop component and grass pea is the minor crop component was practiced by farmers to intensify productivity with a limited use of external inputs. Conversely, the present study confirmed that relay intercropping of rice with chickpea in additive series in the above system was considered to be too risky to cultivate. However, this study was conducted only on one chickpea and rice cultivar and for one planting date of chickpea. Thus, for its effective realization, the following valuable recommendations are also suggested:

- This research was focused on broadcasting of chickpea between rows of rice near to physiological maturity of rice. Further research is essential to evaluate different planting patterns (row and strip relay intercropping) and Planting date of chickpea (time of relayed crop)
- Farmers grow traditional varieties of rice and grass pea with minimum inputs as components to the relay intercropping system; future research should give additional emphasis to evaluate improved varieties of rice (early maturity) and chickpea (early maturity, high temperature tolerance etc.) and improved management practices that can maximize the profitability of the existing cropping system in a sustainable way.
- Future research should also mainly focus on identifying the optimum spacing between rows of rice under rice-chickpea relay intercropping system

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