DETERMINATIONS OF THE SOWING TIME OF GRASS PEA IN TEF- GRASS PEA RELAY INTERCROPPING SYSTEMS

Agegnehu Shibabaw*, Bitwoded Derebe, Yechale Mengie, Oumer Beshir, Wudu Getahun and Alemayehu Assefa

Amhara Region Agricultural Research Institute
Adet Agricultural Research Center
*P. O. Box 08, Bahir Dar, Ethiopia; *Corresponding author e-mail: agegnahus@yahoo.com*

Abstract. Sowing of grass pea immediately after tef harvests as double-cropping is a popular agricultural practice in Vertisols of northwestern Amhara of Ethiopia. However, the productivity of grass pea in the tef-grass pea double cropping system is extremely unreliable due to the shortening of the growing period as a result of climate change. Tef-grass pea relay intercropping has practiced without a defined planting date for grass peas after tef sowing. Therefore, a field experiment was initiated to optimize appropriate sowing date of grass pea for tef- grass pea relay inter cropping systems during 2022 and 2023 main rainy seasons. The treatments contain five sowing dates of grass pea after tef sowing, namely: 35, 50, 65, 80, and 95 days after tef planting, and two contrasting tef verities Viz. Quncho and Tsedey in a factorial combination of a randomized complete block design with three replications. Sole tef, sole grass pea, and farmers practice (grass pea after tef harvested) were included as a check. Plant height, grain yield, and biomass yield were collected and subjected to analysis of variance using the SAS system. The highest grain yield of tef (1388 kg ha^{-1}) and grass pea (1731 kg ha^{-1}), land equivalent ration value (1.79), monitory advantage index (71890 Ethiopian birr) were obtained from planting of grass pea 80 days after Quncho tef sowing. Therefore, planting of grass pea 80 days after Quncho tef sowing appeared to be the most appropriate sowing time to be recommended in Vertisols of Bahir Dar Zuria and North Achefer.

Keywords: double cropping; intensification; land equivalent ratio; sustainable cropping.

INTRODUCTION

Increasing crop production through the increased acreage has been the prime option for a century. However, this is not always an option for most farming operations in the 21th century (FAO., 2017). Land size reduces in many ways despite the fastest growth food need for the ever increasing of world population. As the result, the idea of multiple cropping emerged as a science to meet the growing demand for agricultural commodities. Intercropping, relay cropping, double cropping, mixed cropping practice are the most common practices to intensify our agricultural production (Maitra *et al*., 2021).

Double or relay cropping of tef with grass pea, tef with chickpea, and maize with grass pea and maize with chickpea is common cropping system in Vertisols of northwest Amhara (Yayeh & Fikeremariam, 2015). Growing of grass pea as a relay cropping with rice is drawing attention in Fogera. Rice-grass pea relay cropping a method in which grass pea is seeded into a standing rice crop before harvested. Grass pea is selected to the ability to adapt extreme climatic conditions such as cold, heat, drought and excessive rainfall (Alia *et al*., 2022). It is often broadcasted into standing rice crops 2-4 weeks before the rice harvest(Biswas, 2020). This allows grass pea to

effectively exploit the residual moisture before the rice harvest and the system avoids tillage operations (Yayeh & Fikeremariam, 2015). Such a relay cropping practice is very popular for growing of grass pea in Fogera climate and soil conditions. Relay intercropping facilitates the farmers to cultivate two crops in one year especially in those areas where growing season is shrinking for sequential farming due to climate change (Jabbar *et al*., 2011). Similarly, grass pea relay cropping systems have been shown to be more profitable and sustainable than sole cropping systems in south east Asia (Alia *et al*., 2022). Thus, this mixture seems contributing in the development of sustainable crop production with a limited use of external inputs (Gonçalves *et al*., 2022). It is also reported as a suitable crop for more sustainable production systems such as intercropping. Based on the practice of the rice-grass pea cropping system, the hypothesis of tef-grass pea double cropping developed to increase yield per unit area as both teff and grass pea highly adapted to Vertosols area of the region. Grass pea is highly adapted to residual moisture condition in the district. Grass pea is cultivated with minimum land preparation and without fertilizer application, irrigation and insect, diseases or weed control (Bulbul *et al*. 2019). However, tef- grass pea double cropping constrained by moisture stress due to shrinking of rainy season. As the result, relay intercropping of tef and grass pea is the emerging practice as opposed to tef–grass pea double intercropping systems. Sowing of grass peas before tef harvest helps to use the residual moisture effectively and avoid serious moisture stress in the post rainy season crops.

However, the sowing date of grass pea before tef harvest hasn't been done as opposed to rice-grass pea cultivation. Sowing date is largely determined by the time when the main rains end, soil type, and soil moisture profile during October. Too early planting could add growth competition to main crop and too late planting affect yields due to low moisture in winter months (Assefa & Bitew, 2023). According to Beets (2019) time of planting and the length of overlapping growth period are critical in a relay intercropping system and often lead to excessive growth and harvesting problems. Fixation of planting date enable grass pea to exploit the residual moisture left before tef harvest and avoid tillage operations. However, there is no scientific data on this regard in Ethiopia. As a result, the yields of the component crops expected to vary considerably among farmers. In addition, the productivity of tef-grass pea relay cropping, compared to monoculture and sequential cropping have not been quantitatively documented. Therefore, an experiment was initiated with the objective of determinations of the sowing time of grass pea in tef-grass pea relay intercropping systems.

MATERIALS AND METHODS

Description of the Study Area

A filed experiment was conducted at Bahir Dar Zuria and Achefer district from 2021-2022 main cropping seasons. The study areas largely receive a mono-modal rainfall pattern with maximum rainfall between June and September. Bahir Dare Zuria district is located at 29^0 27′ 34″ to 35^0-58′ 40″ east longitude and 13^0 38′ 19′ to 12^0 10′ 37” north latitude. The elevation of the area ranges from 1774 to 2516 m above sea level. The study area has four major soil types Viz. Vertisols, Nitosols, Luvisols, and Cambisols. Vertisols cover 85,394.9 ha (67.7%); Cambisols cover 13,901.5 ha (11%); Nitosols cover 26,313.5 ha (20.8%); and Luvisols cover 496.5 ha (0.5%) of the total

area (Mohammed, 2021). The dominancy of Vertisols clearly indicates the suitability for tef and grass pea production.

North Achefer District is located 102 km to the west of Bahir Dar, the capital city of Amhara Region. It is geographically located at 11°24′19″ to 13°27′20″ latitude and 36° 22′ 19″ to 37° 33′ 44″E longitudes with an altitude ranging from 1500 to 1800 meter above sea level. The area receives an average annual rain fall ranging from 1000 to 1500 mm and the minimum and maximum day temperature was 25°C and 30°C, respectively (Asmare, 2017). The rainfall in the study area has unimodal distribution with the peak in amount from June to September, during which more than 80% of the annual rainfall is received. The soil is categorized under, clay soil textural class, moderate level of OM and low N fertility levels. Maize, tef and finger millet are among the major cereal crops widely grown in the study area together with the pulses of faba bean, field pea, grass pea, chickpea and with the oil crops of Niger seed, line seed and rapeseed (Abebe *et al*,. 2018)

Treatment Setup

The treatment consisted of five sowing dates of grass pea in days after tef planting (DATP) i.e. 35, 50, 65, 80 and 95 DATP and two contrasting tef verities (*Quncho* and *Tsedey*) in a factorial combination of randomized complete block design with three replications. Sole tef, sole grass pea and farmers practice (grass pea after tef harvested) were included as check. As an additive series intercropping experiment, tef was the base/main crop component and grass pea was the supplementary/intercrop component. Local grass pea has wide adaptability and was selected crop as it has been dominantly grown after tef harvest.

Table 1 Characteristic and requirements of tested varieties

Variety	Altitude (Meter)	Rainfall (mm)	Yield (t ha-1) Research	Farmer	Maturity
DZ-Cr-37(Tsedey	1800-2700	500-1200	1.8-2.8	1.4-1.9	82-90
DZ-Cr-	1800-	800-	2.5-2.7	1.6-	86-151

Source (MOARD, 2006)

The gross and net plot size were 3x2m (6 m^2) and 2.6x1.6 (4.16 m^2) with a distance of 1m and 1.5m between adjacent plots and blocks, respectively. Experimental plots were tilled four times using oxen plough. The seed rates of tef and grass pea were 15 and 75 kg ha^{-1}, respectively with broadcast method of sowing. Fertilizer rate of 80 kg ha^{-1} nitrogen and 40 kg ha^{-1} P_2O_5 was used for tef. Urea was applied ½ at planting and half at tillering stages of tef. No fertilizer was applied on grass pea in all types of cropping systems. The field was weeded twice when the first weeding was done 25 days after sowing, and the second weeding was done 45 days after planting**.** No insecticide or fungicide was applied since there was no outbreak of insects or diseases on tef. Sowing was done from 10-15th July and harvesting was on October 15 to 20$^{th.}$

Data Collection and Analysis

Data of plant height, straw yield and grain yield were collected for tef & grass pea and subjected to analysis of variance using SAS system (SAS,2002). To determine

the grain and straw yield of both component crops, above ground biomass in the net plot area were manually harvested, collected and sun dried until constant dry weight was attained. All data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design using SAS (SAS, 2002). Least significant difference (LSD) test at 5% level of probability was used for mean separation as procedure described by Gomez and Gomez, (1984).

Indices

***Land Equivalent Ratio*:** is the amount of land required to provide the same yield as an intercropping system when mono cropping is utilized. The LER was calculated using the formula suggested by (Mead, 1980). It is calculated by determining the ratio of the yield of a crop in a mixture with its yield in a monoculture.

$$LER = \frac{\text{Intercrop teff yield}}{\text{Sole teff Yield}} + \frac{\text{Intercrop grass pea yield}}{\text{Sole grass peaYield}}$$

Area Time Equivalent Ratio (ATER): provides more realistic comparison of the yield advantage of intercropping over mono cropping in terms of time taken by component crops in the intercropping systems. The **ATER** was calculated using the formula suggested by (Hiebsch, 1987)

$$\text{ATER} = ((\text{LER TEff xDC TEFF}) + (\text{LERGRASS PEA} \times \text{ DC GRASS PEA}))/\text{Dt}$$

LER=land equivalent ratio of crop, DC = duration (days) taken by crop, Dt= is days to intercropping system from planting to harvest.

***Agressivity*:** indicates the relative yield increase in crop "a" compared to crop "b" in an intercropping situation (Willey & W., 1979)

$$\text{Aab} = \frac{\text{Yab}}{\text{yaa}}\text{x Zab} - \frac{\text{Yba}}{\text{ybb}}\text{xZba}$$

Where Yaa and Ybb = pure stand yield of tef and grass pea. Yab and Yba = intercropping yield of teff and grass pea. Zab and Zba = the area time equivalent ratio of the crop tef and grass pea when intercropping, respectively.

***Monetary Advantage Index*:** calculated to give some economic evaluation of intercropping as compared to sole cropping. The monetary advantage index was calculated by the formula developed by **(Wille, 1979)**

$$\text{MAI} = (\text{Value of combined intercropping}) \times (\frac{\text{LER} - 1}{\text{LER}})$$

RESULT AND DISCUSSION

The pooled analysis of variance of the sowing time of grass pea in tef-grass pea relay intercropping systems showed that the grain yield of tef was highly significantly (*P<0.01*) affected by year, and significantly *(P<0.05*) affected by variety, and the interactions of variety and sowing time (Table 2). The grain yield of grass pea was highly significantly (*P<0.01*) affected by year, variety and the interaction of variety and sowing time in tef-grass pea relay intercropping systems. The straw yield of tef

and grass pea were highly significantly (*P<0.01*) affected both variety and sowing time and the interactions. The changes in grain and straw yield for teff varieties might be due to the genetic makeup of the two varieties. The change in grain and straw yield of teff might be the manifestation of interspecific competition among component crops during crop growth periods.

Table 2**.** Mean squares of analysis of variance for the effects of variety and sowing time on straw and grain yield teff-grass pea relay intercropping systems in combined over locations and years

Source of variation		Tef		Grass pea	
		Grain yield	Straw yield	Grain yield	Straw yield
Year (Yr)	1	4251.23**	3.21n	2145*	1.25ns
Variety (Vr)	1	6871763*	94.14*	1224.20**	46.49**
Sowing time (St)	5	1285391.4ns	2.73**	25.63**	1.34**
Replication (Rep)	2	6062.2ns	0.26n	28.103ns	1.67ns
Vr*Yr	3	335240.8ns	0.51n	34.1334n	2.110n
St*Yr	2	87043.2ns	0.21n	6.161ns	3.19ns
V*St	6	318055.4*	0.69**	46.432*	1.09**

*ns= not significant; * =significant at (P<0.05) level; **=highly significant at (P< 0.01) level; DF=Degree of freedom*

The grain and straw yield of tef showed highly significant (*P< 0.01*) difference in response to the interactions effects of the sowing time of grass pea and variety in tef-grass pea relay intercropping systems in both years (Table 3 & 4). The highest grain yields (1634 kg ha^{-1}) in 2022 and (1367 kg ha^{-1}) in 2023 were recorded at sole cropping systems. Following the sole systems, sowing of grass pea 90 days after tef planting showed the highest grain and straw yield tef and was statistically at pare with sole tef sowing systems in both years. The grain yields of tef were 1521 kg ha^{-1} in 2022 and 1323 kg ha^{-1} in 2023 at sowing of grass pea 95 days after for *Quncho* tef variety. The lowest grain yields (1078 kg ha^{-1}in 2022 and 882 kg ha^{-1} in 2023) were recorded at early planting of grass pea, 35 days after sowing for *Tsedey* tef. Correspondingly, the grain yield of grass pea showed significant (*P< 0.01*) difference in response to the interaction effects of the sowing time of grass pea and variety in tef-grass pea relay intercropping cropping systems. Similar to the grain yield of tef, the seed yield of grass pea was higher in sole grass pea planting systems (2154 kg ha^{-1} in 2022 and 2023 kg ha^{-1} in 2022) of grass pea was recorded in sole cropping system. Following to the sole cropping system, planting of grass pea after 80 days of tef planting showed the highest seed yield. The grain yields were 2011 kg ha^{-1} in 2022 and 1511 kg ha^{-1} in 2023 at planting of grass pea after 80 days of tef planting. The highest yield at sole cropping system in both crops is due to the absence of interspecific competition in sole cropping systems. The highest seed yield of grass pea after 80 days of tef planting might be due

to late planting of grass pea takes advantage in peak resource demands for nutrients, water, and sunlight. The decline in grain yield of both grass pea and tef with early time of intercropping is associated to shading effect of tef over grass pea, which hindered the plants' photosynthetic activity. The result is in consistence to Bulbul *et al*., (2019) who showed inappropriate date of planting in intercropping significantly lower the yield of both crops due to overlapping of peak resource demand. The result is also in line with the findings of Cagasan & Amarado (2023) when peanut was planted 2 weeks ahead of upland rice harvest obtained the heaviest weight of seed.

The LER of teff-grass pea relay intercropping systems are presented in Tables 3 and 4. Land equivalent ratio showed variations in response to tef grass pea-relay inter cropping systems in both years. The highest total land equivalent ration value (1.84) was recorded at planting of grass pea 80 days after planting of *Quncho* tef variety and followed by 80 days after tef planting in 2022. Similarly, in 2023 the highest land equivalent ratio value (1.75) was obtained from planting grass pea after 80 days of *Quncho* tef variety and was statistically at par with the planting of grass pea after 65 days of tef planting. The lowest yield advantage in terms of total LER value obtained at planting of grass pea after 35 days of tef sowing and followed by 50 days after tef planting. In most scenarios the LER was greater than unity, indicating that intercropping is very much advantageous than sole cropping systems. Planting of grass pea at late stage of tef was found appropriate time for grass pea- tef relay intercropping.

Data combined over locations and years, the grain and straw yield of tef showed highly significant ($P< 0.05$) difference in response to the interactions effect of tef variety and sowing time of grass pea in tef-grass pea relay intercropping cropping systems (Table 5). The highest grain yield (1500 kg ha^{-1}) of tef was obtained in sole planting systems. Following sole cropping system, the highest grain yields of tef (1423 kg ha^{-1}) was recorded when grass pea was planted 95 days (October 1st) after tef sowing. In contrast, the lowest grain yield of tef were recorded when grass pea was planted35 days after tef sowing. Like tef, the seed yield of grass pea showed significant ($P< 0.05$) difference in response to the interaction effects of the sowing time of grass pea and tef variety. The highest grain yield (2102 kg ha^{-1}) was obtained on sole planting systems. Planting of grass pea after 80 days of *Quncho* tef harvesting showed the highest seed yield (1388 kg ha^{-1}) following sole sowing system. To the contrary, the lowest grain yield of grass pea (1026 kg ha^{-1}) was recorded at 35 days (planting on August 20th) after *Tsedey* tef variety sowing. In most scenarios sole cropping showed higher yield than the intercrop. In sole cropping system, interspecific competition is absent and fair resource competition exists within variety. This result is in line with the findings of Yayeh & Fikeremariam (2015) who reported that all the agronomic attributes of rice and chick pea were maximum in sole cropping. However, the grain yield of tef and grass pea in combined increased in intercropping situation compared to the sole systems.

In both crops, as the length of overlapping period increases, the yield of tef and grass pea decreases with the maximum yield on sole cropping systems and the lowest yield on the earlier planting of grass pea (35 days) after tef sowing. Earlier planting of grass pea before 80 days after tef sowing remarkably reduced the combined grain yield of tef and grass pea over sole systems. The lowest yield of on the longest inter cropping period might be due to the presence of high interspecific competition between tef and grass pea. An early planting of grass pea in relay intercropping system coincide with

peak resource demands of tef to nutrients, water, and sunlight that stiff competition especially for light. Early planting also enhances shading and excess moisture on the intercropped grass pea by tef, which hindered the plants' photosynthetic activity.

Planting of grass pea after 80 days of tef (September 15th) sowing was statistical at pare with the sole cropping systems. This showed competition among crops is negligible after September 15th (80 days after tef sowing) planting and might be the right time for grass pea planting after tef sowing. This might be due to the better ability of grass pea to take up residual moisture from the soil. Grass pea effectively utilize the residual moisture and germination and establishment was found maximum in late sowing times between 80 and 95 days after tef sowing. The result is in conformity with Sarma, (2020) who showed highest rice equivalent yield of 1335 kg ha^{-1} with relay cropping of pea at 15 days after rice flowering. Gupta (2005) reported that sowing of grass pea 15-20 days before rice harvest gave a better result in respect of yield, probably due to the fact that earlier sowing might have more effective utilization of residual moisture in the rice field. Planting of grass pea near to harvesting and immediately after abruptly reduce the grain yield of grass pea due to the rapid dwindling of soil moisture before the crop has established. Thus, planting grass pea as farmers' practice (after tef harvest) leads to lower yield than between September 15th and October 1st planting dates due to soil moisture depletion.

In combined over locations and years, total land equivalent showed remarkable difference in response to tef-grass pea relay intercropping systems. The highest land equivalent ration value of 1.79 and 1.69 were recorded when grass pea is planted 80 and 95 days (October first week) days after *Quncho* tef sowing, respectively. While the lowest LER value of 0.79 recorded at planting of grass pea 35 days (August second week) sowing date after tef planting. In most treatment combinations, the LER is more than unity. This indicates the intercropping is advantageous and the combined yield of grass pea and tef in the mixed system were higher than sole tef and grass pea alone. In this particular intercropping the farmer would need as much as 1.34 to 1.79 hectares of land when crops are grown in sole in order to achieve the same yield level from one ha of land. The result is in line with Sharma **(**2004) who reported crop intensification through inclusion of grass pea increase the total productivity and land use efficiency. Higher equivalent yields due to legume intercropping were also reported and grass pea sowed immediately before rice harvest. The result in line with Gonçalves, **(**2022.) who showed broadcast grass pea on the saturated soils in the standing rice field about 15-20 days before the rice harvest ensure germination and can be the more appropriate timing of planting for optimum crop production.

Monetary, Agressivity and Area Time Equivalent Ratio Values

Total income, Agressivity, area time equivalent ratio and monetary advantage index of tef-grass pea relay intercropping cropping systems showed variation in combined over locations. Maximum total income (ETB =162890 ha^{-1}) and monetary advantage index (ETB =71890 ha^{-1}) were recorded when grass pea was planted 80 days after *Quncho* tef variety followed by grass pea planted 95 days after *Quncho* tef variety with total income (ETB=156690 ha^{-1}) and monetary advantage index (ETB =63974 ha^{-1}) gained. The lowest total income (ETB=53900.00 ha^{-1}) was recorded when grass pea was planted after 35 days of *Quncho* tef planting. Agressivity also showed variation in response to cropping systems. Agressivity value of 0.78 was higher when planting of

grass pea after 35 days of tef planting. Agressivity value of 0.10 was minimum when grass pea was planted after 80 days of tef sowing. On the other hand, monetary advantage index values were positive which showed a definite yield advantage in intercropping compared to sole cropping (Willey 1979). According to Aasim (2008), it is an indicator of the economic feasibility of intercropping systems as compared to sole cropping. Area time equivalent ratio (ATER) value varied in response to tef-grass pea relay intercropping systems. Planting of *Quncho* tef variety after 65 days showed area time equivalent ratio of more one. This suggests that those relay inter cropping have a yield advantage over mono-cropping and may be the appropriate timing of planting of the component crops to maximize crop yield per unit area per unit time.

Table 3 The effects of variety and sowing time on yield and land equivalent ratio of tef-grass pea relay intercropping systems in 2022 crop season

Treatments		Tef		Grass pea		Land equivalent ratio		
Variety	Grass pea sowing date	Grain yield (kg ha^{-1})	Straw yield (t ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (t ha^{-1})	Tef	Grass pea	Total
Quncho	35	1253bcd	3.23de	-	-	0.76	0.00	0.76d
	50	1463bbc	3.6cd	300f	1.45f	0.90a	0.13	1.03c
	65	1477bc	3.66bcd	1725cd	2.46de	0.90a	0.80c	1.71ab
	80	1488ab	4.04abc	2011b	2.65cde	0.91a	0.93a	1.84ab
	95	1521ab	4.1ab	1869cb	2.97ab	0.93a	0.77c	1.70ab
Tsedey	35	1078f	2.17g	-	-	0.66c	0.00	0.66e
	50	1124f	2.2g	562.f	1.65f	0.69c	0.26	0.95a
	65	1207ef	2.32g	1693d	2.43e	0.74c	0.79c	1.52b
	80	1330de	2.57fg	1877cb	2.74bc	0.81b	0.87ab	1.69ab
	95	1350cd	2.916ef	1603cbd	2.72bcd	0.83b	0.74d	1.57b
Sole tef	July 15th	1634a	4.2a	-	-			
Sole GP	October 1st	-	-	2154a	3.22a			
GPATH	October 15th	1134	2.4	804ef	1.6			
CV%		10.83	12.56	7.8	11.8	10.2	9.6	11.1
Means		1357	3.12	1672	2.49			
Standard Error			0.78	0.42	0.133	0.087	0.42	0.31
Significance		**	*	**	*	**	*	*

Table 4 The effects of variety and sowing time on yield and land equivalent ratio of tef-grass pea relay intercropping systems in (2023)

Treatments		Tef		Grass pea		Land equivalent ratio		
Variety	Sowing date of grass pea	Grain yield (kg ha^{-1})	Straw (t ha^{-1})	Grain (kg ha^{-1})	Straw	Tef	Grass pea	Total
Quncho	35	1097ab	2.9ed	0.0	0.00	0.80	0.0	0.8
	50	1263ab	3.3bdc	210f	1.2e	0.91	0.1	1.1
	65	1276ab	3.3bc	1211ed	2.2dc	0.915	0.7	1.62
	80	1287a	3.7abc	1451b	2.58ab	0.925	0.82	1.75
	95	1323a	3.8ab	1268bc	2.73ab	0.95	0.69	1.64
Tsedey	35	882e	1.8g	0.00	0.00	0.655	0.00	0.65
	50	928e	1.9g	493f	1.36e	0.685	0.25	0.93
	65	1008e	2.0g	1132e	2.03d	0.74	0.675	1.41
	80	1128bc	2.2fg	1312cd	2.51bc	0.815	0.76	1.58
	95	1155cd	2.6ef	1118cd	2.68ab	0.835	0.69	1.52
Sole tef	July 15th	1367a	4.0	0.0	0.0			
GP	October 1st	-	-	2023	2.9a			
GPATH	October 15th	1072	2.1	1004	2.31bc			
CV%		11.62	14.23	11.53	13.76			
Means		1156.2	2.82	1218.85	2.27			
Standard Error		2.1	3.1	1.2	0.4			
Significance		**	*	**	*			

**ns= not significant; * =significant at (P<0.05) level; **=highly significant at (P< 0.01) level; DF=Degree of freedom; GP= grass pea; GPATH=grass pea after tef harvest*

Table 5. The effects of variety and sowing time on yield and land equivalent ratio of tef-grass pea relay intercropping systems in combined over locations and years

Treatments		Tef		Grass pea		Land equivalent ratio		
Variety	Sowing date (DAS)	Grain yield (kg ha^{-1})	Straw yield (t ha^{-1})	Grain yield (kg ha^{-1})	Straw Yield (t ha^{-1})	Tef	Grass pea	Total
	35	1175a	2.9ed	0.00	0.00	0.79	0.00	0.79
Quncho	50	1363a	3.3bdc	255e	1.3e	0.79	0.12	0.91
	65	1377a	3.3bc	1468c	2.3d	0.80	0.69	1.52
	80	1388a	3.7abc	1731a	2.6c	0.81	0.82	1.79
	95	1423a	3.8ab	1568.5ab	2.8ab	0.83	0.74	1.69
Tsedey	35	980d	1.8g	0.00	0.00	0.57	0.00	0.57
	50	1026d	1.9g	527.5d	1.5e	0.59	0.25	0.84
	65	1108bc	2.0g	1412.5c	2.2d	0.64	0.67	1.34
	80	1229b	2.2fg	1594.5ab	2.6bc	0.71	0.71	1.47
	95	1253b	2.6ef	1360.5c	2.7bc	0.73	0.64	1.37
Sole tef	July 15th	1500.1a	3.75a	0.00	0.00			
Sole GP	October 1st	-	-	2102a	3.0a			
GP after tef harvest	October 15th	1103	2.2	904cd	1.95			

CV%		10.12	15.79	12.4	13.08
Means		1256.08	2.93	1501.52	2.4
Standard Error	0.7	2.4	3.4	0.91	
Significance	**	*	**	*	

**ns= not significant; * =significant at (P<0.05) level; **=highly significant at (P< 0.01) level; DF=Degree of freedom; GP= grass pea; GPATH=grass pea after teff harvest*

Table 6. Total income, Agressivity, area time equivalent ratio and monetary advantage index tef-grass pea relay intercropping cropping systems in combined over locations

Treatments		Tef	Grass pea						
Variety	Sowing Date	Grain Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Tef income (ETB ha^{-1})	Grass pea income (ETB ha^{-1})	Total Income (ETB ha^{-1})	Agressivity	ATR	MAI
	35	1175	00.00	64625	0.00	64625	0.78	0.42	-17178.80
Quncho	50	1363	255.0	74965.00	12750.00	87715.00	0.79	0.53	-8675.11
	65	1377	1468	75735.00	73400.00	149135.00	0.22	1.00	51019.87
	80	1388	1731	76340.00	86550.00	162890.00	0.10	1.04	71890.00
	95	1423	1568.5	78265.00	78425.00	156690.00	0.20	1.01	63974.02

	35	980	0.00	53900.00	0.00	53900.00	0.65	0.62	-40661.40
Tsedey	50	1026	527.5	56430.00	26375.00	82805.00	0.43	0.54	-15772.38
	65	1108	1412.5	60940.00	70625.00	131565.00	0.07	0.90	33382.16
	80	1229	1594.5	67595.00	79725.00	147320.00	0.06	0.91	47102.31
	95	1253	1360.5	68915.00	68025.00	136940.00	0.19	0.81	36983.80
Sole tef	July 15th	1500.1	0.00			82505.5			
Sole GP	October 1st	-	2102			105100.00			
Sole GPATH	October 15th	-	1605			80250.00			

**GP= grass pea; GPATH=grass pea after tef harvest; ATR=area time ratio, MAI= monetary advantage index*

CONCLUSION

Early planting of grass pea in tef-grass pea relay intercropping system leads to significant yield reduction of both crops while late planting of grass pea in the relay intercropping system was found optimum. In most of tef-grass pea relay intercropping combinations, the land equivalent ratio was greater than unity, indicating that relay intercropping is very much advantageous than sole cropping systems. The highest grain yield of tef (1388 kg ha^{-1}) and grass pea (1731 kg ha^{-1}), land equivalent ration value (1.79), monitory advantage index (71890 Ethiopian birr) were obtained from planting of grass pea 80 days after *Quncho* tef sowing (about 15th Sept) followed by 95 days after *Quncho* tef sowing (about 1st of October). Therefore, planting of grass pea 80 to 95 days after *Quncho* tef sowing appeared to be the most appropriate sowing time range to be recommended in Vertisols of Bahir Dar Zuria and North Achefer.

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REFERENCE

1. Abebe Zeleke, Getachew Alemayehu & Yihenew Gebreslasie (2018). Effects of planting density and nitrogen fertilizer rate on yield and yield related traits of maize (Zea mays L.) in Northwestern, Ethiopia. *Advances in Crop Science and Technology*,*6*(2):125-130. doi: 10.4172/2329-8863.1000352.
2. Alia, M., Rahmana, J. & Islamb, T. (2022). Relaying of different grass pea cultivars with t. aman rice under jamalpur region. *International Journal of Life Science Study*. doi: 10.7508/ijlss.01.2022.04.06.
3. Asmare Bimrew & MekuriawYeshambel (2017). Assessment of livestock production system and feed balance in watersheds of North Achefer District, Ethiopia. Journal of Agriculture and Environment for International Development (111(1):175-190.doi: 10.12895/jaeid.2017111.574.
4. Beets, W. (2019). Multiple cropping and tropical farming systems. CRC Press.
5. Biswas, B. (2020). Branching out: Relay grass pea (*Lathyrus sativa* L.) Production on rice fallows in the eastern Indo-Gangetic Plains. *International Journal of Current Microbiology and Applied Sciences 9*(1):836-838. doi: 10.20546/ijcmas.2020.901.091.
6. Bulbul, A., Khadiza, K., & Shafikur R. (2019). Growth and yield performance of grass pea (*lathyrus sativus l.*) under different methods of sowing and pre-emergence irrigation. *Advances in Biological Research 13 (3): 89-94,DOI: 10.5829/idosi.abr.2019.89.94*. doi: 10.5829/idosi.abr.2019.89.94.
7. FAO (Food and Agricuiture Organization)(2017).The future of food and agriculture:- Trends and challenges. Rome,Itali.
8. Gomez, A. (1984). Statistical procedures for agricultural research. 2nd edition.
9. Gonçalves, L., Rubiales, D., Bronze, M.& Vaz P.(2022). Grass pea production is sustainable and resilient answer to climate challenges. *Agronomy 12*(6): 1324. doi: 10.3390/agronomy12061324.
10. Hiebsch, C. (1987). Area time equivalency ratio: A method of evaluating the productivity of intercrops.*Agronomy Journal* 79:15-22. http://dx.doi.org/10.2134/agronj1987079000.
11. Jabbar A., Ahmad R., Bhatti I. & Mea, N. (2011). Residual soil fertility as influenced by diverse rice-based inter-relay cropping systems. *International Journal of Agriculture and Biology* 13(4). 124-129.

12. Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H. & Sairam, M. (2021). Intercropping: A low input agricultural strategy for food and environmental security. Journal of *Agronomy, 11*(2): 343. doi: 10.3390.+
13. Mandal, L. & Muha, K. (2014). Evaluation of cereal-legume intercropping systems through productivity and competition ability. *Asian Journal of Science and Technology 5(3): 233–237.*
14. Mead, R. (1980). The concept of land equivalent ratio and advantages in yields from intercropping. Experimental Agriculture, 16(4):217-228. http://dx.doi.org/10.1017/S001.
15. Ministry of Agriculture and Rular Development (MARD) (2006). Crop variety regestration.issue 9.PP:17-18
16. Mohammed, N. & Asmamaw, D. (2021). Remote sensing and GIS-based soil loss estimation using RUSLE in Bahir Dar Zuria District, Ethiopia. In soil Erosion-current challenges and future perspectives in a changing World. IntechOpen.
17. Nuttapon K.,Wanwisa P. & Georg C. (2021). Early planting and relay cropping: pathways to cope with heat and drought? *Journal of Agriculture and Rural Development in the Tropics and Subtropics 122(1):61–71-https://doi.org/10.17170/kobra-202104133652.*
18. SAS 2002. Statistical software analysis using the SAS System. Cary, NC, SAS Institute Inc.
19. Tanveer, M., Anjum, S., Hussain, S., Cerdà, A. & Ashraf, U. (2017). Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production. *Environmental Science and Pollution Research, 24*:6973-6988.
20. Willey, R. (1979). Intercropping-its importance and research needs. Agronomy and research approaches
21. Yayeh Bitew & Fikeremariam Asargew. (2015). Rice and chickpea relay intercropping systems in an additive series experiment in rain fed lowland ecosystem of fogera vertisols. Scientific Journal of Review 4(1): 10-16.
22. Yazachew Fikre, Dargo Fentahun, Kebede Worku & Solomon Chanyalew, Kebebw Assefa, Sewagegn Tarikegn, Esuyawkal Demis and Asaye Birhanu. (2001). Performance evaluation of tef varieties for yield and yield related traits in traditional and non-traditional growing areas under irrigation production in Ethiopia. *Journal of Plant Sciences 9(6): 313-319. doi: doi: 10.11648/j.jps.2*.
23. Yazachew Fikre, Fana Kebede, Worku Chanyalew, Solomon Tolosa, Kidist Assefa, Kebebw Tarikegn, Sewagegn Demis and Esuyawkal Birhanu (2021). Performance evaluation of tef varieties for yield and yield related traits in traditional and non-traditional growing areas under irrigation production in Ethiopia. *Journal of Plant Sciences 9*(6): 313-320. doi: 10.11648/j.jps.20210906.16.