6. Evaluations of Grass Pea (*Lathyrus sativus*) Relay Inter-Cropping and Its Mulching Effect on Vertisols in Eastern Amhara Region, Ethiopia

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Abstract

Studies on the management of Vertisols have mainly concentrated on waterlogged soil drainage systems rather than on diversifying agricultural productivity. Inter cropping is one of the diversification techniques used in agricultural practice. Ethiopia has historically grown grass pea for food and livestock feed, and huge portions of the nation also produce wheat. The land's ability to produce crops was boosted in order to aid in the improvement of Vertisols productivities. Nine field experiments were carried out, two grass pea planting time integrated with two wheat row spacing and two soil drainage planting techniques. Each treatment was set up with randomized complete block design in three replications. The analysis result show that at tillering stage of wheat planting grass pea on furrow and between rows with in 30cm spacing is more effective than others. It contributes a significant value to soil fertility status and soil moisture contents. Grass pea is a legume crops it incorporates Nitrogen and it also used as a cover crop which retain soil moisture. This type of planting technique also efficient in case of land utilizations. A total of 1.9 ha of sole cropping area would be required to produce the same yields as 1 ha of the intercropped system. Planting of grass pea during the tillering stage of wheat crop with 30 cm spacing is recommended while farther studies in case of economic impact is needed.

Keywords: Grass pea, land equivalent ratio, planting time, Vertisols, Wheat

Introduction

The origin of grass pea cultivation is around 6000 Before Christ (De Ron, 2015). *Lathyrus sativus* L. or grass pea (Guaya in Ethiopia) has been cultivated in South Asia and Ethiopia for over 2500 years and is used as food and feed. Its tolerance to drought, not affected by excessive rainfall and can be grown on land subjected to flooding, including very poor soils and heavy clays (Jiang *et al.*, 2013). The world's population is increasing rapidly, and in order to feed it, one of the most attractive strategies is to increase productivity per unit area of available land or to increase the land area under production, which seems shrinking day by day (Snapp *et al.*, 2005). Therefore, to maximize land use and production, the ultimate goal of agriculture, namely yield, intercropping is an advanced agronomic technique that allows two or more crops to yield from the same area of land. Better utilization of resources and reduced weed competition minimize the risk of food shortages by enhancing yield stability (Aziz *et al.*, 2015).

In Ethiopia, Vertisols cover about 12.6 million ha of land, or about 10% of the total area of the country (Asamenew *et al.,* 1993). These soils have great potential for crop production since they have relatively good inherent fertility and are located mainly in the highlands where rainfall is sufficient. Grass pea has been an important crop both for human consumption and for animal feed or fodder since ancient times.

Food shortages are common in many parts of the world, particularly in Asia and Africa, due to population growth. One possible solution to this dilemma is to boost productivity per unit area of available land by maximizing the use of limited agricultural land through multiple cropping (Seran and Brintha, 2010). Intercropping is a crop management strategy that involves cultivating two or more dissimilar crop species or kinds in separate row combinations on the same piece of land at the same time (Yildirim and Guvenc, 2005).Intercropping has been demonstrated in numerous studies to be more productive than monoculture, yet it can also result in resource rivalry (Aziz *et al.,* 2015). One of the many competing resources in crop production systems is light, and soil moisture is another one that could be a competitor (Harper and Glyde 2010).

It is a legume crop grown in arid and semi-arid regions that is well known for being extremely drought tolerant (Campbell, 1997). This crop is a high protein content and remarkable resistance to extreme environmental conditions, such as flooding, drought, salinity, and low soil fertility, as well as a significant amount of resistance to biotic stress agents (Jiang *et al.*, 2013).

In Ethiopia, it is the third most important pulse crop after Fababean (*Vicia faba*) and chick pea. Mostly planted in September / October on residual moisture in the cambisol and vertisol**.** It can withstand heavy rains in the early growth stages and prolonged drought during grain filling (Girma and Korbu, 2012; Hillocks and Maruthi, 2012). Before the first crop is harvested, growing one crop and then planting another one in the same field helps with computation and extends the usage of the field (Debele Berhanu, 1985; Snapp *et al.*, 2005).

In this study, the experiment was carried out using a relay inter cropping system using wheat and grass pea crops. Wheat yields and grain protein content are lower and more variable in organic conditions than in conventional agriculture, mainly due to Nitrogen (N) deficiency and weed competition. The under sowing of legume cover crops in growing winter wheat, also known as relay intercropping, is assumed to be a proficient way of enriching the soil-crop system with Nitrogen and improving weed control *(Amossé et al., 2013)*.

Relay inter cropping systems have the advantages of being affordable and simple to grow without requiring much work. Grass pea offers a variety of distinctive qualities that appeal to both growers and customers. Which are: Withstanding adverse environmental circumstances including drought and high moisture, it can be grown with very little input. It enhanced food security in harsh environments, low input livestock feed and as a cover crop for soil conservation. In relay intercropping, wherein late-season crops are planted in rows whereas early-season crops are still growing (Gao *et al.*, 2014). Therefore, the ultimate goal of this study is in order to evaluate the effectiveness of grass pea relay inter cropping with wheat for better productivity and to evaluate its effect on soil moisture and soil fertility improvement.

Materials and Methods

Experimental Site Description: The study was conducted in main cropping season during 2019 and 2020 in Jama district, that lies 10^{o} 23'to10^{o}27'N latitudes and 39^{o}07' to 39^{o}24'E longitudes. The dominant soil type of the study districts Vertisols, the area is characterized by poor drainage or water logging, difficulty to work (Belete *et al.,* 2013). The area receives an average annual rainfall of 1012.0 mm of which 74.6% is received during the main rain season (June to September) and the highland plateau of Jama has a very cold temperature which ranges from 0 to 20^{o}c. The nature of its soil type is gray clay with high swelling and shrinking character. It is poorly drained when wet and cracking when dry. The land use is mostly cultivated field crops: wheat (*Triticum aestivum*), tef (*eragrostis tef*), and fabba bean (*Vicia faba*) in rotation, while the marginal lands along the roadsides and communal pasture lands purposely left for feed sources are the major grazing grounds (Lebay *et al.*, 2021).

Experimental Design: Nine field experiments were carried out, two grass pea planting time integrated with two wheat raw spacing and two drainage planting techniques. Each treatment was set up with randomized complete block design in three replications. The plot size was adjusted 4.8mx3m and the spacing between plot and replication is 1m by1.5m respectively. The land preparation and agronomic practices have been adopted the farmers practice of the study area.

The planting time of wheat was in the second week of July. After a month or at tillering stage of wheat (mid-August) grass pea was planted as inter cropping. The conventional planting time of grass pea was starting from September first week.

The locally recommended Nitrogen and Phosphorus fertilizers (69 Kgha^{-1} Nitrogen and 46 Kgha^{-1} Phosphorous) was applied in splithalf at planting and half at knee height. The agronomic results were analyzed statistically and tested using F-test to estimate the least significant difference at % level of significant.

Table 1. Experimental treatments

Treatments	Grass pea Planting time	Grass pea Planting practiceand wheat planting spacing
1	Tillering stage of wheat	Planting on furrows only (20cm)
2	Tillering stage of wheat	Planting on furrow and between row (30 cm)
3	Tillering stage of wheat	Planting between rows (30 cm)
4	Conventional planting time of grass pea	Planting on furrows only (20cm)
5	Conventional planting time of grass pea	Planting on furrow and between row (30 cm)
6	Conventional planting time of grass pea	Planting between rows (30 cm)
7		Sole cropping of wheat (20 cm)
8		Sole cropping of wheat (30 cm)
9		Sole cropping of grass pea

Soil Sampling Technique and Methods of Analysis: Soil moisture content was taken after the last grass pea planting time (in dry season); 15 day late after the rainfall. For soil moisture and bulk density, the sample was taken from the surface 0 up to 20 cm. For soil moisture analysis, soil data from 0-20cm was taken during wheatharvesting time (Funakawa *et al*., 2012). Then the soil moisture content was analyzed by the gravimetric method and soil bulk density (Blake, 1965), soil organic matter and soil pH also done by volumetric, wet digestion and water and Potassium chloride suspension method respectively in addition total Nitrogen and available Phosphorous was analyzed by Kjeldahl and Olsen procedure respectively (Walkley, 1934).

Methods of Agronomic Data Analysis: The agronomic data was analyzed statistically and tested using the F-test to estimate least significant difference at 5% level of significance. In addition land equivalent ratio also calculated based on in the following formula for both sole and inter cropping area coverage with the proportional yield productions (Yilmaz *et al*., 2008).

$$LER \quad \frac{\text{YG in mixed stand}}{\text{YG in pure stand}} + \frac{\text{YW in mixed stand}}{\text{YW in pure stand}}$$ LER=Land equivalent ratio (FAO 1976)

YG= Yield of grass pea and YW = Yield of wheat

Results

Effect of intercrops on crop yield and biomass production: In this trial, relay intercropping had no impact on wheat grain production, independent of the chance to grow a grass pea crop. Wheat biomass and yield did not significantly differ from one another in terms of production potential, however grass pea production potential varied according on the treatments (Table 1 and Table 2).

Table 2. Grain Yield (GY) and Biomass Weight (BWT) of grass pea and wheat in 2019

Treatments		Gy Wheat Kgha^{-1}	Bwt Wheat Kgha^{-1}	Gy Grass pea Kgha^{-1}	Bwt Grass pea Kgha^{-1}
Tillering stage of wheat	• Planting on furrows only (20cm)	2432a	6632a	602c	1818b
	• Planting on furrow and between row (30 cm)	2501a	6458a	1436bc	4747a
	• B/n rows (30 cm)	2218a	6250a	1331bc	3939ab
Conventional planting time of grass pea	• Planting on furrows only (20cm)	2254a	6562a	872bc	2449b
	• Planting on furrow and between row (30 cm)	2491a	6181a	1637b	5101a
	• Planting between rows (30 cm)	2501a	6944a	922bc	2424b
Sole cropping of wheat (20 cm)		3224a	7917a	-	-
Sole cropping of wheat (30 cm)		2266a	6181a	-	-
Sole cropping of grass pea		-	-	2625a	6086a
CV		21.1	17.3	36.90	31.45
LSD		ns	ns	884.0*	1717.2*

**= significant. ns= non-significant. a, b and c= level of similarity*

The second-year result also in lined with the previous yield and biomass of wheat and grass pea production. Since planting of grass pea at tillering stage of wheat with 30cm of wheat is more productive from the other treatments (Table 3).

Table 3. Grain Yield (GY) and Biomass Weight (BWT) of grass pea and wheat in 2020

Treatments		Gy Wheat Kgha^{-1}	Bwt Wheat Kgha^{-1}	Gy Grass pea Kgha^{-1}	Bwt Grasspea Kgha^{-1}
Tillering stage of wheat	• Planting on furrows only (20cm)	1667a	5595a	976.9ab	2803a
	• Planting on furrow and between row (30 cm)	1906a	6823a	1508.5a	3535a
	• B/n rows (30 cm)	1752a	7083a	1064.2ab	2210ab
Conventional planting time of grass pea	• Planting on furrows only (20cm)	1687a	5387a	369.1b	1193 b
	• Planting on furrow and between row (30 cm)	1805a	6042a	882.9ab	2247ab
	• Planting between rows (30 cm)	2005a	5469a	271.4b	1136b
Sole cropping of wheat (20 cm)		2014a	6518 a	-	-
Sole cropping of wheat (30 cm)		1545a	5208a	-	-
Sole cropping of grass pea		-	-	1524.8a	3580a
CV (%)		24.5	20.3	43.3	34.6
LSD(0.05)		772.402	2138.27	725.3	1469.98

Figure 1. Grass pea planting on furrow and row of wheat space

The above illustration depicts a wheat and grass pea crop covering the entire land. Even though the ground's surface was cracked from the dryness, the grass pea covers the entire plot, helping to reduce soil surface evaporation. The grass pea used to cover the land used to alleviate the surface cracking (Figure 1).

Table 4. Combined result over years

Treatments		Gy Wheat $Kgha^{-1}$	Bwt Wheat $Kgha^{-1}$	Gy Grasspea $Kgha^{-1}$	Bwt Grasspea $Kgha^{-1}$
Tillering stage of wheat	• Planting on furrows only (20cm)	2049ab	6114	790bc	2311cd
	• Planting on furrow and between row (30 cm)	2204ab	6641	1472ab	4141ab
	• B/n rows (30 cm)	1985ab	6667	1198bc	3074bcd
Conventional planting time of grass pea	• Planting on furrows only (20cm)	1971ab	5975	620c	1821d
	• Planting on furrow and between row (30 cm)	2148ab	6111	1260bc	3674abc
	• Planting between rows (30 cm)	2253ab	6207	597c	1780d
Sole cropping of wheat (20 cm)		2619 a	7217	-	-
Sole cropping of wheat (30 cm)		1905 b	5694	-	-
Sole cropping of grass pea		-	-	2075a	4833a
CV		16.5	14.8	31.2	23.9
LSD		618.3	ns	635.5	1316.02

Intercropping for Effective Utilization of Land Resource: Intercropping results in increased yields because environmental resources are utilized effectively. Combinations, especially cereal/legumes blends, can help with sustainable agriculture and effective land use.

An interpretation of this result would be that a total of 1.9 ha of sole cropping area would be required to produce the same yields as 1 ha of the intercropped system. This result was recorded from the treatment of tillering stage of wheat with planting on furrows and between row spacing of 30cm (Table 5).

Table 5. Land equivalent ratio (LER)

Treatments		LER
Tillering stage of wheat	Planting on furrows only (20cm)	1.2
	Planting on furrows and b/n row (30cm)	1.9
	Planting on rows (30cm spacing)	1.6
Conventional planting time of grass pea	planting on furrows only (20cm)	1.1
	Planting on furrow and b/n row (30 cm)	1.4
	Planting on rows (30cm spacing)	1.5
Sole cropping of wheat (20 cm)		1
Sole cropping of wheat (30 cm)		1

Impact of Intercropping on Soil Fertility and Conservation Status: The soil moisture content was obtained after the rainfall decreased in August since the first soil moisture sample was taken in September, the second in December, and the third in January, respectively. The findings revealed that while there was no significant variation between the first two samples, there was a difference during the final measuring period (Table 6). In case of soil health status, it could improve the soil productivity with improving soil moisture content and enhancing basic soil macro nutrients (Table 6, 7 and 8).

Table 6. Soil moisture content (SMC) and bulk density (BD) in 2019

Treatments		SMC% 07-02-2019	SMC% 11-03-2019	SMC% 10-04-2019	BD(g/cm3)
Tillering stageof wheat	• Planting on furrows only (20cm)	26.8	15.2	6.5ab	1.4
	• Planting on furrow and between row (30 cm)	24.3	15.9	7.2b	1.3
	• Planting between rows (30 cm)	22.4	14.8	5.1ab	1.29
Conventional planting time of grass pea	• Planting on furrows only (20cm)	28.0	16.2	6.8b	1.6
	• Planting on furrow and between row (30 cm)	25.0	17.8	3.5ab	1.28
	• Planting between rows (30 cm)	22.3	14.5	4.2ab	1.4
Sole cropping of wheat (20 cm)		23.7	19.4	2.5c	1.5
Sole cropping of wheat (30 cm)		26.2	18.1	2.9c	1.4
Sole cropping of grass pea		23.0	16.0	14.7a	1.3
Cv		15.5	15.53	14.28	9.77
LSD		ns	ns	3.5*	0.24*

The bulk density or soil compaction indicator of the results showed that the treatments differed significantly from one another. This showed that the principal crops should be spaced 30 cm apart from the row and furrow planted with grass peas (Table 6).

Table 7. Soil moisture content (SMC) and bulk density (BD) in 2020

Treatments		SMC% 05-01-2020	SMC% 10-04-2020	SMC% 20-05-2020	BD (g/cm3)
Tillering stage of wheat	• Planting on furrows only (20cm)	26.8	9.5	8.5	1.2ab
	• Planting on furrow and between row (30 cm)	26.2	10.4	8.7	1.1a
	• Planting between rows (30 cm)	25.5	9.8	7.6	1.1a
Conventional planting time of grass pea	• Planting on furrows only (20cm)	29.1	9.4	9.2	1.1a
	• Planting on furrow and between row (30 cm)	26.6	10.2	7.6	1.3ab
	• Planting between rows (30 cm)	27.3	8.9	8.1	1.3ab
Sole cropping of wheat (20 cm)		27.7	10.5	7.3	1.4b
Sole cropping of wheat (30 cm)		24.5	5.2	7.8	1.4ab
Sole cropping of grass pea		31.7	11.3	9.4	1.2ab
Cv		9.5	20.6	17.0	8.8
LSD		ns	ns	ns	*

Table 8. Soil chemical property status of the soil

Treatments		%OM	%Tot.N	Avi.P (ppm)	PH
Tillering stage of wheat	• Planting on furrows only (20 cm)	1.36[ab]	0.187	7.4ab	6.5
	• Planting on furrow and between row (30 cm)	1.43[ab]	0.163	9.0a	6.4
	• Planting between rows (30 cm)	1.30[ab]	0.150	7.2ab	6.4
Conventional planting time of grass pea	• Planting on furrows only (20cm)	1.41[ab]	0.187	6.7ab	6.4
	• Planting on furrow and between row (30 cm)	1.34[ab]	0.160	5.3b	6.2
	• Planting between rows (30 cm)	1.58[a]	0.150	7.1ab	6.5
Sole cropping of wheat (20 cm)		1.10[b]	0.173	6.6ab	6.4
Sole cropping of wheat (30 cm)		1.26[ab]	0.187	7.8ab	6.4
Sole cropping of grass pea		1.29[ab]	0.150	6.7ab	6.3
Cv (%)		19.26	14.02	15.05	1.77
LSD (0.05)		*	ns	*	ns

Discussion

Intercropping of cereal and pulse crops have been maximized the productivity potential of the land and increased the land use efficiency. While it does contribute to maximizing the efficiencies of the cultivated field, this sort of cropping system has little impact on the output potential (Amossé *et al.*, 2013). According to many authors, it makes an argument based on all of its implications. When main crop and inter crop have separate growing seasons such that their principal resource demands are met at different times, the yield advantage have be at its highest (Aziz *et al.*, 2015). The component crops in intercropping are concurrent throughout a sizable amount of their production cycle or growing period, even though they may not be planted or harvested at precisely the same time (Srivastava *et al.,* 2008). Contrary to single crop systems, intercropping systems often result in higher yields *(Lithourgidis et al.,* 2007).

Utilizing plant growth factors effectively is important for assessing the benefits of intercropping in sustainable agriculture to fulfill the growing demand for food caused by population growth. That is if LER >1 is used to indicate that intercropping is superior to solo crops in terms of light, water, and Nitrogen use (Corre-Hellou et al., 2009; Liu *et al.,* 2018). The intercrops' land equivalent ratios (LER) values ranged from 1.08 to 1.21 at both harvest stages (Hauggaard-Nielsen et al., 2006). According to some studies, different intercrops use plant growth elements up to 50% more effectively than a single crop (Hauggaard-Nielsen *et al., 2001)*. Under conditions of low Nitrogen fertilization, pea and barley intercropping also utilized environmental resources for plant growth more effectively than a single crop (Cowell, L. and Bremer, Eric and Kesel, 1989). Thus crops are similar in most characteristics of wheat and grass pea.

Because intercropping uses resources like light, water, and nutrients more effectively than a single crop, it generally results in higher yields (Mousavi and Eskandari, 2011). With the use of the Land Equivalent Ratio, it is possible to precisely evaluate the competitiveness of the intercropping system's component crops, effective land use, and total production (Maitra, 2019). A popular index used in intercropping is the land equivalent ratio, which is used to gauge the productivity of the land (Seran and Brintha, 2009). A land equivalent ratio larger than one indicates that the land is being used more effectively in an intercropping system. The benefits of cereal-legume intercropping were demonstrated by LER due to more effectively using resources in intercropping by increasing plant density (Osiru and Willey, 1972; Fisher, 1977).

Various literatures indicated that, if the land and furrow should be covered by the crop was possible to sustain the surrounding moisture (Shaxson, Barber and Food and Agriculture Organization of the United Nations, 2003). The main crop raised on the bed was grown well with substantial amount of yield could be harvested on the furrows without affecting the main crop on the bed (Kathuli and Itabari, 2014).

In Italy, cultivation of grass pea almost stopped but there is renewed interest in the crop to provide an efficient alternative to wheat on land degraded by excessive cereal cultivation (Grandgirard *et al.,* 2002).

Due to its very strong and deep-reaching root system, grass pea is tolerant to different soil pHs, and is capable of growing and developing on different soil types, which makes it unique among legumes (Campbell, 1997).

Conclusion and Recommendation

The influence of relay intercropping of what and grass pea on productivity and soil property status has been assessed. As a result, the time and planting technique of grass pea were taken into account in order to assess the effectiveness of grass pea relay intercropping with wheat for increased productivity as well as its impact on soil moisture and fertility. As a result, the findings indicate that planting grass pea alongside wheat did nothave a substantial impact on wheat production potential, but it did contribute to additional output in the specific parcel of land. Since grass pea planting during the wheat tillering stage is more effective in every way. Wheat planting, on the other hand, should be spaced 30 cm apart.

The covering of grass pea, which is employed for Nitrogen fixation and soil surface covering, has had an impact on the soil moisture and fertility status of the land. As a result, the grass pea furrow was covered, indicating a higher soil moisture content and fertility quality. While some qualities did not indicate a significant difference, the majority of soil chemical and physical parameters show a greater differential improvement in the covering of the land's bed and furrow.

To increase output potential and soil fertility, farmers should be instructed to employ release intercropping on vertisoil with grass pea planting at the tillering stage of wheat. The cropping technique also should be prepared the broad bed and furrow based on its recommendation and sowing of wheat at 30 cm spacing. The grass pea should be sowing with in the wheat row and entire the furrow. Cropping techniques should also include preparing the broad bed and furrow according to the manufacturer's recommendations, as well as sowing wheat at 30 cm spacing. In the wheat row and throughout the furrow, the grass pea should be sown.

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