Effect of Intra Row Spacing and Tillage on Yield and Yield Components of Maize Pigeon Pea Cropping System

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Abstract— **Inclusion of legumes in cropping system can play an increasingly important role to sustain crop production and ensure food security in small holder farmers. The present study initiated with the objective to identify compatible spacing between pigeon pea plants under maize plants with conservation tillage and conventional tillage on growth and yield of component crops. Treatments consisted of three intra row spacing (20,30,40,50 cm) of pigeon pea under maize recommended spacing and two tillage practices (conservation tillage and conventional farmers practices) were lied in randomized complete block design and replicated three times. Maize variety BH546 was used with spacing of 80*40 cm (2 seeds per hill) and Pigeon pea Hindi variety was used in between maize rows based on the intra row spacing of pigeon peato their respective treatments. Fertilizer and field management deployed as to recommendation for maize production. Environment (location by year) had highly significant effect on all maize parameters tested.The highest stand count (45), plant height (247cm), Ear height (138 cm), number of cobs harvest (44). Above ground biomass (18369 kg -ha) were observed from Boricha in 2019. On the other hand, the highest 367g thousand seed weight and 6297kg ha-1 grain yield were from Halaba in 2020. Maize crop was not affected by tillage methods and pigeon pea spacing. The response of all parameters tested for pigeon pea significantly (p<0.05) influenced by environment, tillage and intra row spacing. Thus, maize with either of the pigeon pea intra row spacing and minimum tillage can provide alternative option for resource poor farmers to ensure food security through improved grain yield of component crops at all tested locations.**

Index Terms— **competitive, complimentary, cropping system, , productivity.**

I. Introduction

Maize (Zeta mays) is one of the most important cereal crops in the world ranked second to wheat production, first in Africa and Latin America but third after rice and wheat in Asia. Globally, maize is grown over an area of 193 million hectares with production of 1.15 billion tons annually [1]. The crop is the most important staple crop feeding more than 200-300 million people across Africa and providing food and income security to millions of smallholder farmers.In Ethiopia, it is grown on over 2 million hectares and ranked first among cereal in total production and productivity. According to the Central statistical agency [2]report of the country, maize covered 21 % (2135572 hectares) of the cereal crop area and contributed to 31% (7847174.7 tons) of the cereal production. In Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia, maize covered 37 % (322714 hectares) of the cereal crop area and contributed to 51% (1085725.6 tons) of the cereal production with 3.36 tons ha^{-1} productivity [2]. In spite of the enormous uses of maize and higher volume of production**,** its productivity in the region is generally low, ranging from 2.2 t ha^{-1} (Segen people's zone) to 4.0 t ha^{-1} (Silte zone[2]. This is far below the potential yield of maize that could be achieved with the currently available technologies in the country.

Pigeonpea [Cajanus cajan (L.) Millspaugh] is often cross pollinated (20-70%) out crosses crop with 2n=2x=22 diploid chromosome number belongs to the family Leguminoseae. India is considered as the native of pigeonpea because of its natural genetic variability available in the local germplasm and the presence of its wild relatives in the country. It is the sixth most important legume crop in the world. It is a tropical grain legume and is among important pulses grown for food, feed and soil fertility improvement. Apart from the use of grain, farmers make use of pigeonpeain various ways depending on their ethnic groups and locality [3]. Pigeon pea is fast growing, hardy, widely adaptable, and drought resistant [4]. The extensive root system of Cajanus cajan improves soil structure by breaking plow pans, and enhances water holding capacity of the soil. Nutritionally, Pigeon pea (Cajanus cajan) is a legume reported to contain 20-22% protein, 1.2 % fat, 65% carbohydrate and 3.8% ash FAO [5]. Pigeon pea contains more minerals, ten times fatter, five times more vitamin A and and three times more vitamin C than ordinary peas. Though mainly cultivated for its edible seeds, Cajanus cajan can be considered a multipurpose species [6]. Pigeon pea stems are a good fuel source, valued for its fast-growing habit though their energy value is half that of charcoal. Stems and branches of pigeon pea are also used for basketry. In Colombia, pigeon peas are cultivated for feed but once for beans and once for forage[4]. Medicinal uses of pigeonpea to treat ailments such as dizziness, snake bite, measles is determined by farmers' location and ethnic group[3].Pigeonpea is an indeterminate photoperiod sensitive and perennial plant by nature. The space available to the individual plant decides the quantum of soil moisture, mineral nutrients and light energy tapped by the plant. Ahlawat et al. [7]reported that wider row spacing (75 cm) produced more branches per plant than narrow row spacing (50 cm).

Limited availability of additional land for crop production, lack of improved crop varieties, decreased soil fertility and declining yield for major food crops have been cited as the major concerns for agriculture's ability to provide

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nourishment for the increasing population. Increased yield, disease resistant and quality are the ultimate goals in almost any crop improvement programs. However, it seems that reasonable yields with few risks are preferable than high yields with high risks to the resource poor farmers living in the tropics under highly variable environments. The inclusion of legumes in cropping system has significant impact on land productivity. However, agronomic recommendations like spacing either between plants and or between rows in both crop combination is worthwhile. There is little or no information for maize/ pigeon pea intercropping and the spacing between pigeon pea plants under maize population. Thus, the present study was initiated to identify compatible spacing between pigeon pea plants with conservation tillage and conventional tillage on yield and yield components of component crops.

I. MATERIALS AND METHODS

Descriptions of the study areas: Field experiments were conducted during 2018 and 2020 cropping seasons at three locations namely; Halaba, Boricha and Lokaabaya districts of Southern Ethiopia. Halaba on station with clay loam textured soil having pH 6.8 =, EC = 0.08 ds/m, total N (%) = 0.44, available P = 37.6 ppm) and altitude of 1800 m.a.s.l. whereas, Boricha located at 6.93^{o} latitude of and 38.42^{o} longitude having initial soil pH value of 6.32, 2.44 OC, 0.17 total N and 25.93 CEC, and Loka-abaya having 7.10^{o} latitude and 38.15^{o} longitude with 6.15 pH, 2.75 OC, 0.20 total N, and 24.88 CEC, using farmers field as representing location in Southern region of Ethiopia. There is bimodal rainfall pattern locally termed belg (short rainy season starting from February and ends late May) and meher (main rainy season starting from early June and ends late September) for the locations.

Treatments of the experiment. Treatments consisted of three intra row spacing (20,30,40,50 cm) of pigeon pea under maize normal spacing and two tillage practices (conservation tillage and conventional farmers practices) were lied in randomized complete block replicated three times. Maize variety BH546 was used with spacing of 80*40 cm (2 seeds per hill) and Pigeon pea Hindi variety was used in between maize rows based the intra row spacing according to the respective treatments. Fertilizer and field management deployed as to recommendation for maize production.

A. Data collected:

Maize

Stand count, plant height (Plant height (cm) of five randomly select plant heights were measured from the ground level to bases of tassel and averaged at 90% physiological maturity of maize crop), ear height measured from ground level as to that of plant height to the height where cobs initiated, cobs harvested (counting total cobs harvested from harvestable areas of the plot), above ground biomass (plants in net plot areas where harvested and the weight measured using conventional measuring balance, then converted to hectare). , thousand seed weight was measured by counting 1000 random seeds from a plot yield and measured using sensitive balance, grain yield (yield obtained from net plot area was measured using measuring balance and finally converted to hectar base adjusting 12.5% moisture content of the grain) and harvest index was calculated as the ratio of grain yield to biomass yield of a plot.

Pigeon pea

Plant height, number of branches per pod, pods per plant, seeds per pod above ground biomass, thousand seed weight, grain yield and harvest index were the data collected. (Plant height (cm) of five randomly select plant heights were measured from the ground level to bases of flower and averaged, the total number of branches and pods of five selected plants were counted and averaged as number of branches per plant and pods per plant, in that order. In each pod there are number of seeds, seeds of five randomly selected pods were counted and their averages were recorded as number of seeds per pod, above ground biomass (plants in net plot areas where harvested and the weight measured using conventional measuring balance, then converted to hectare). , thousand seed weight was measured by counting 1000 random seeds from a plot yield and measured using sensitive balance, grain yield (yield obtained from net plot area was measured using measuring balance and finally converted to hectare base adjusting 10% moisture content of the grain).

B. Data analysis

Data were subjected to analysis of variance (ANOVA) according to the Generalized Linear Model (GLM) procedure of SAS (Statistical Analysis System) Version 9.0 [8] and interpretations were made following the procedure of Gomez and Gomez[9]. When there was detection of significance difference among treatments means, separation was done using Least Significance Difference (LSD) test at 5% level of significance.

II. RESULTS AND DISCUSSIONS

A.Maize data

As presented in table 1, environment (location by year) had highly significant effect on all parameters tested. However, intercropped pigeon pea and their interaction had no significant effect on the parameters except thousand seed weight. The highest stand count (45), plant height (247cm), Ear height (138 cm), number of cobs harvest (44). Above ground biomass (18369 kg -ha) was observed from Boricha in 2019. On the other hand, the highest 367g thousand seed weight and 6297kg ha-1 grain yield was from Halaba in 2020 (Table 2). Similarly, Senkoro and his colleagues who elaborated pigeon pea intercropping was compatible with maize due to the slower growth rate and later maturity of pigeon pea relative to that of maize which reduces inter-species competition for growth resources [10] growing several plant species together naturally involves competitive interactions – either for nutrients, light or water. But such interactions are not necessarily a handicap as long as complementarity is stronger than competition and improves the overall use of resources [11]

Table 1. mean square values for the effect of intra row spacing and tillage on maize plant height, ear height, number of cobs harvested, thousand seed weight, above ground biomass, grain yield and harvest index.

Source of variation	df	Stand count	Plant height	Ear height	Cobs harvested	seed weight	Biomass yield	Grain yield	HI
Env. (L*Y)	5	97**	6092**	4289**	77**	135436**	170.21*	15.97*	0.313
Tret (T)	7	20ns	242ns	149ns	20ns	330ns	5.50	1.08ns	0.005
E*T	35	16ns	119ns	98ns	24ns	513*	8.51	0.84ns	0.003
Error	94	15	121	104	21	282	3.41	0.64	0.003
Total	143								
Cv%		9.15	4.95	8.53	11.06	7.28	13.27	14.48	11.87

Table 2. The effect of environment (location by year) to intra row spacing of pigeon pea and tillage on maize plant height (cm), ear height (cm), number of cobs harvested, thousand seed weight(g), above ground biomass (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index.

Environment		Stand count	Plant height	Ear height	Cobs harvested	seed weight	Biomass yield	Grain yield	HI
Lokabaya	2019	42bc	233b	129b	41ab	227c	9375e	5998a	0.64a
	2020	43ab	225c	119c	39c	176e	9375de	5288b	0.57b
Halaba	2018	39d	203e	100e	41ab	257b	10152d	4153c	0.41c
	2020	42bc	211d	111d	44a	367a	14701b	6297a	0.43c
Boricha	2018	40cd	217cd	120c	41ab	165f	12934c	5122b	0.40c
	2019	45a	247a	138a	44a	192d	18369a	6181a	0.34d
$LSD_{0.05}$		2.19	6.32	5.84	2.63	9.62	897	456	0.03

As presented in table 1 above, all the parameters tested were statistically not significant to tillage methods and pigeon pear spacing under on maize growth and yield. The probable reason might be due to the fact that extensive root system of Cajanus cajan improves soil structure by breaking plow pans, and enhances water holding capacity of the soil, thus is less competitive effect of the pigeon pea intercrop with maize on maize growth and yield. According to [12] the capacity of plants to acquire provisioning resources under intercropping depends on the result of both complementarity plant facilitation processes, all occurring in the field but at varying levels. Complementarity is mainly responsible for limiting competitive interactions by improving resources partitioning, while facilitation provides additional services by improving environmental growth conditions and resources availability. The intercropped pigeonpea has a longer growth cycle, and when sown simultaneously can continue to grow for up to three months after maize harvest [13]. The extended period of growth ensures that the greatest demand for water and nutrients in pigeonpea occurs after maize has been harvested[14].The slow initial growth of pigeonpea makes it well suited for intercropping as there is little competition with the primary maize crop [15].

Table 3. effect of intra row spacing and tillage combination on maize plant height (cm), ear height (cm), number of cobs harvested, thousand seed weight(g), above ground biomass (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index

Treatments	Stand count	Plant height	Ear height	Cobs harvested	seed weight	Biomass yield	Grain yield	HI
T1S1	43	225	122	42	225	12969	5624	0.46
T1S2	43	228	121	43	227	12830	5944	0.49
T1S3	42	225	123	41	235	12118	5305	0.45
T1S4	43	225	119	42	228	13160	5474	0.46
T2S1	41	221	121	42	232	12471	5651	0.47
T2S2	40	219	115	40	230	11991	5344	0.47
T2S3	42	223	119	41	238	12176	5548	0.48
T2S4	41	217	115	41	230	12147	5160	0.44
$LSD_{0.05}$	Ns	Ns	ns	ns	ns	ns	ns	Ns

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4is 40cm intra row spacing between pp plants.

Table 4. The interaction effect of environment and treatments on thousand seed weight of maize

Treatments	Environments					
	Lokabaya		Halaba		Boricha	
	2018	2020	2018	2020	2018	2019
T1S1	232	165	265	321	180	187
T1S2	227	176	249	341	167	200
T1S3	231	185	248	377	163	205
T1S4	233	168	261	364	161	181
T2S1	228	176	265	366	165	194
T2S2	221	181	245	392	158	186
T2S3	232	184	257	400	168	186
T2S4	213	178	265	377	155	193
SE±	6.92	7.14	8.43	25.96	7.63	8.07

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4is 40cm intra row spacing between pp plants

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As discussed earlier, either intra raw spacing or tillage methods did not affect the seed weight of maize. On the other hand, environment and treatment combination had significant effect on thousand seed weight. The highest 400g was from Halaba during 2020 in conventional tillage with 40cm pigeon pea intra row spacing (Table 4). most probable reason for this might be the complementary effect of intercropped pigeon root system, which improve soil fertility through its root system and nitrogen fixing ability.Similarle, Ngenga et al., [16], in their study on Farm-scale assessment of maize–pigeonpea productivity in Northern Tanzania indicated that the large amount of pigeonpea leaf fall which is left in the field after harvest can contribute greatly to soil fertility through nutrient cycling and maintenance of soil organic matter for long term sustainability. Residual benefits that the intercropped legume crops and in particular pigeonpea provide to the subsequent maize crop deserve more detailed investigation. Furthermore, since intercrops are known to increase aggregate yields per unit input through complementarity in utilization of nutrients, water and solar radiation, studies to assist in quantification of such benefits are strongly recommended.

Pigeon pea data

The response of all parameters tested for pigeon pea significantly ($p<0.05$) influenced by environment (Loc*year), tillage and intra row spacing (T). However, seed weight and grain yield of the crop were not affected. Similarly, environment and the treatments interaction significantly influenced plant height, seeds pod $^{-1}$, above ground biomass and thousand seed weights (Table5).

Table 5. mean square values for the effect of intra row spacing and tillage on pigeon pea plant height, branches plant -1, seeds pod-1, pods plant-1, biomass, seed weight and grain yield.

Source of variation	df	Stand count	Plant height	Branches plant -1	Seeds pod-1	Pods plant-1	Biomass yield	Seed weight	Grain yield
Environment (L*Y)	5	39ns	2831**	126*	0.19*	3707**	839299339**	5817**	12287174
Treatment (T)	7	2075**	839**	26**	0.62**	5866**	64642835**	29ns	76489
E*T	35	21ns	250**	7ns	0.34*	1505ns	31366496**	84**	241379
Error	94								
Total	143								
Cv%		15.13	5.30	19.65	10.30	31.58	34.65	4.78	40.72

Table 6. The effect of environment (location by year) to intra row spacing and tillage on pigeon pea plant height (cm) branches plant $^{-1}$, number of seeds pod^{-1}, pods plant^{-1}, above ground biomass (kg ha^{-1}), thousand seed weight(g)and grain yield (kg ha^{-1}).

Environment		Stand count	Plant height	Branches plant -1	Seeds pod-1	Pods plant-1	Biomass yield	Seed weight	Grain yield
Lokabaya	2019	29	205b	13b	5	198b	16673a	117d	377c
	2020	31	212a	13b	5	84d	12386b	152a	748d
Halaba	2018	27	189c	10c	4	64e	2787c	138ab	1098bc

	2020	30	213a	13b	4	85d	12040b	151a	1362ab
Boricha	2018	30	212a		4	104c	3490c	142b	1226b
	2019	29	193c	16a	4	219a	3737c	118c	2482a
LSD $_{0.05}$		ns	6.21	1.52	ns	22.77	1692	3.74	284

As presented in table 6, the highest (2.48t ha^{-1}) grain yield, most important agronomic parameter was obtained at Boricha during 2019. The probable reason might be the amount and even distribution of rainfall in the study area.

Table 7. The effect intra row spacing and tillage on pigeon pea plant height (cm) branches plant $^{-1}$, number of seeds pod^{-1}, pods plant^{-1}, above ground biomass (kg ha^{-1}), thousand seed weight(g)and grain yield (kg ha^{-1}).

Environment	Stand count	Plant height	Branches plant -1	Seeds pod-1	Pods plant-1	Biomass yield	Seed weight	Grain yield
T1S1	46ab	207bc	12d	4.4bc	110c	10715ab	137	1253
T1S2	28bc	202c	14ab	4.3bc	128bc	9438b	138	1303
T1S3	24c	207bc	15a	5.8a	124bc	7890bc	137	1221
T1S4	20d	211a	15a	4.6ab	158a	7506bc	135	1236
T2S1	46a	202c	13cd	4.3bc	122bc	11595a	135	1230
T2S2	30b	202c	12d	4.2c	110c	7954bc	136	1167
T2S3	23cd	210ab	15a	4.3bc	147ab	6926c	136	1232
T2S4	19e	190d	13cd	4.3bc	109c	6125c	138	1084
LSD$_{0.05}$	2.95	7.16	1.76	0.3	26.29	1953.7	ns	ns

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4is 40cm intra row spacing between pp plants.

For most of the parameters tested, there was significant effect among treatments (tillage and spacing combination). Here the focus was on aboveground biomass, which is the alternate source for animal feed in drier seasons, fuel wood and fertility restoration when the leave allowed to decompose. The highest 11.6 t ha^{-1} above ground biomass obtained from conventional tillage with narrow spacing (Table 7).

Table 8. The interaction effect of environment by treatments on plant height(cm) of pigeon pea

Treatments	Environments					
	Lokabaya		Halaba		Boricha	
	2018	2020	2018	2020	2018	2019
T1S1	220	207	192	199	231	194
T1S2	200	209	191	198	222	194
T1S3	205	220	194	211	218	196
T1S4	229	215	187	221	221	195
T2S1	202	212	181	219	204	194
T2S2	187	222	186	228	203	187
T2S3	208	224	191	226	212	202
T2S4	193	192	187	200	188	178
SE$\pm$	13.69	10.34	4.19	12.47	13.62	7.15

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4 is 40 cm intra row spacing between pp plants.

Table 9. The interaction effect of environment by treatments on aboveground biomass (t ha-1) of pigeon pea

Treatment	Environments					
	Lokabaya		Halaba		Boricha	
	2018	2020	2018	2020	2018	2019
T1S1	20.79	18.26	2.57	15.66	4.34	2.67
T1S2	17.67	16.77	3.16	9.90	4.10	5.04
T1S3	13.22	12.77	3.26	9.51	3.96	4.62
T1S4	10.84	11.38	3.44	10.42	3.96	5.00
T2S1	31.29	14.60	2.19	15.42	2.99	3.09
T2S2	14.48	10.01	2.33	15.66	2.50	2.74
T2S3	10.93	9.97	2.85	10.73	3.33	3.75
T2S4	14.17	5.33	2.50	9.03	2.74	2.99
SE$\pm$	6.79	4.18	0.51	2.98	0.87	1.05

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4is 40cm intra row spacing between pp plants.

As presented in table 9, The highest 31.29 t ha^{-1} above ground biomass was obtained from conventional tillage with narrow spacing at Lokaabaya during 2018 cropping season (Table 9) followed by conservation tillage with the same narrow intrarow spacing at Lokaabaya during 2018, while the least (2.19 t ha^{-1}) was obtained from conventional tillage at narrow intra row spacing of pigeon pea at Halaba during 2018.

Table 10. The interaction effect of environment by treatments on thousand seed weight (g) of pigeon pea

Treatment	Environment					
	Lokabaya		Halaba		Boricha	
	2018	2020	2018	2020	2018	2019
T1S1	114	150	139	147	155	116
T1S2	115	152	137	152	153	119
T1S3	116	151	134	151	142	125
T1S4	107	155	139	153	138	116
T2S1	124	148	135	149	139	114
T2S2	120	153	135	156	133	120
T2S3	116	154	143	154	137	111
T2S4	125	150	145	150	137	121
SE±	5.82	2.36	3.98	2.93	7.98	4.41

T1=conventional recommended extension tillage practices and T2 is the conservation tillage, S1is 20cm intra row spacing between pp plants, S2 is 30cm intra row spacing between pp plants, S3 is40cm intra row spacing between pp plants, S4is 40cm intra row spacing between pp plants.

The highest thousand seed weight of 149g was obtained from a treatment combination of conventional tillage with narrow pigeon pea intra row spacing at Halaba during 2020 cropping season while the least 107g was from conservation tillage at wider intra row spacing at Lokabaya during 2018 cropping season.

III. CONCLUSION AND RECOMMENDATION

Legumes are a rich source of food proteins that are generally grown under risk prone marginal lands. Amongst various food legumes, pigeon pea occupies an important place and has been rated the best as far as its biological value is concerned. It can be grown both as an annual crop or perennial plants in homestead and is consumed either as decorticated splits or in the form of green seeds as vegetables. Environmenthad highly significant effect on all parameters tested. The highest stand count (45), plant height (247cm), Ear height (138 cm), number of cobs harvest (44). Above ground biomass (18369 kg -ha) were observed from Boricha in 2019. On the other hand, the highest 367g thousand seed weight and 6297kg ha-1 grain yield of maize were from Halaba in 2020. However, pigeon pea intra row spacing with tillage combination had no significant effect on maize growth and yield. The response of all parameters tested for pigeon pea significantly ($p<0.05$) influenced by environment and treatment combination (tillage and intra row spacing). However, seed weight and grain yield of the crop were not affected. Similarly, environment and the treatments significantly influenced plant height, seeds pod -1, above ground biomass and thousand seed weights.

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