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Determination of Effective Spatial Arrangement for Intercropping of Maize (*Zea mays* L.) and Potato (*Solanum tuberosum* L.) Using Competition Indices Ethiopia

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Abstract

An experiment was conducted on the determination of effective spatial arrangement for intercropping of maize and potato using competition indices at South Wollo, Ethiopia for two consecutive years, 2010-2011. The objective of the study was to determine effective spatial arrangement for intercropping of maize and potato. The treatments were 1 maize:1 potato, 2 maize:2 potato, 1 maize:2 potato (a), 2 maize:1 potato (a), 1 maize:2 potato (b) and 2 maize:1 potato (b). Sole maize and sole potato was used for comparison. JMP 5 (SAS) software's were used to compute the analysis of variance. The combined yield advantages in terms of total land equivalent ratio (LER) and Income equivalent ratio (IER) indices were greatest in the cases of 1 maize:1 potato followed by 1 maize:2 potato (b) intercropping arrangement. Area time equivalent ratio (ATER) values showed an advantage of 75.0% only in 1 maize:1 potato. Effective Monetary advantage (EMAI) index was highest in 1 maize:2 potato (b)followed by 1 maize: 1 potato intercropping arraignments. However, Competitive ratio (CR) values for all crops in all intercropping arrangements were less than one indicating both crops are equally competitive. Based on the this findings, 1 maize: 1 potato followed by 1 maize:2 potato (b) intercropping arrangement gave the highest PRY, LER,ATER, IER and EMAI; and lowest CR value and in turn achieve higher productivity rates of the two crops, which lead to favorably recommend the use and utilization of this system in south wollo. It is recommended that this project was conducted for two years, there was lack of budget and hence this research should be repeated in different agro ecology and spatial arrangement.

Keywords: Maize; Potato; Intercropping arrangement; LER; ATER IER; EMAI; CR

Introduction

Nowadays food problem is one of the most important problems in the world, attributed to the drastically growing numbers of population, limited cultivation areas and occurrence of diseases, insect pest etc. due to climate change [1]. Among the different areas of Ethiopia, South Wollo is chronically food insecure. The economy is based on crop production (sorghum, Teff and maize) and livestock rearing. This implying the immense need for more extensive research in order to accommodate the problem. Agriculture is the key to solve famine problem, a lot of researches conducted in Ethiopia expressed the possibility of increasing the yield by many means and cultivation innovative techniques, which is not limited to the use disease resistance plants, finding a new cultivars with a good quantity and quality, or in utilizing the utmost of existing resources in countries [2].

The use of agricultural intercropping system is one method of increasing crop productivity and intensity of crops [1]. Crop productivity in intercropping system depends on many factors including variety used, plant density, planting arrangement, cropping seasons and agricultural practices like irrigation, fertilization etc. [3]. Intercropping system proved achieving many advantages, such the perfect utilization of environmental factors, soil protection and variety of food resources [4]. On the other hand, Ofori et al. [5] indicated that intercropping system causes a decrease of yield due to the problems of harmful grasses, pests and diseases, in addition to the difficulties of harvesting.

Most of the intercropping system researches in Ethiopia have concentrated on field crops intercropped with legume crops, like Soya bean, haricot bean, Faba bean intercropped with maize and sorghum [6]. However, there are a number of studies on intercropping system about potato and maize. Some of these include Midmore et al. [7], Liu et al. [8] and Bouwe et al. [9] studied a combination of potato and maize, in Latin America, Asia and Africa, respectively.

In combining of potato and maize together in an intercropping system, where the growth pattern of potato and maize leaves differs, the light competition decreases the growth and affects leaves formation [1]. Other results for Cahill et al. [10] showed that root competition in the first stages of plant's life cycle leads into weak growth and decreases plant light interception. Another study conducted Ebwongu et al. [11] results showed that productivity of the potato crop decreased when intercropped with maize compared to the plantation of sole potato, while; it increased by increasing plant density during intercropping treatments. In addition to that researches results done by Dutta [12] indicated that land equivalent ratio was highest under intercropping system compared with sole cropping. However, no research studies answers which maize-potato intercropping spatial arrangement were the best.

In many parts of Ethiopian, maize intercropping with potato is the common practice to increase the production per unit area. However, its management practice follows simple natural principles, and its practice is limited only by the imagination of farmers (one row of maize planted with one row of potato). No published studies have been made to improve the productivity of this kind of planting system. As a result, the yields of the component crops vary considerably among farmers. Therefore the objective of this study was to determine the effective spatial arraignment for maize and potato intercropping using competition indices.

Materials and Methods

Site description

This research was carried out at Combolcha Agricultural technical Vocational Education and Training College (TVET) research farm, south wollo, Ethiopia for the period of two growing seasons of 2010 to 2011. It is located in an altitude between 1705 and 3000 m. The major soil classifications are Camisoles, Phaeozems, and Litho sols [13]. Mean annual temperatures range between 15 and 20°C. Annual rainfall, which is heavy during the summer months (June-August), ranges between 800 and 1200 mm [13].

Experimental design and treatments

A complete randomized-blocks design was used in this study, containing six intercropping systems, one sole maize and one sole potato treatments with 3 replicates. The gross plot area was 5 m × 6 m (30 m^2). The distance between each plots and replications was 1 m and 1.5 m, respectively. Potato was planted in 10 cm depth. Regarding potato fertilization, 165 kg/ha UREA and 195 kg/ha DAP were used. In the case of maize 100 kg/ha DAP and 200 kg/ha UREA were used. All other the agronomic practices were conducted as per the recommendation given by ministry of agriculture and rural development.

Tested treatments were listed as follows:

1. Potato was planted between rows of maize (maize planted in 75 cm × 25 cm) (1 maize:1 potato)
2. Two rows of maize planted with two rows of potato (maize and potato planted in 75 cm × 25 cm and distance between potato and maize is 37.5 cm) (2 maize:2 potato)
3. One row of maize planted with two rows of potato (potato was planted in 75 cm × 25 cm and distance between potato and maize is 37.5 cm) (1 maize:2 potato (a))
4. Two row of maize planted with one rows of potato (maize was planted in 75 cm × 25 cm and distance between potato and maize is 37.5 cm) (2 maize:1 potato (a))
5. One row of maize planted with two rows of potato (potato was planted in 75 cm × 25 cm, distance between potato and maize is 37.5 cm and maize planted in intra row spacing of 20 cm) (1 maize:2 potato (b))
6. Two row of maize planted with one rows of potato (maize was planted in 75 cm × 25 cm , distance between potato and maize is 37.5 cm and potato was planted in intra row spacing of 20 cm) (2 maize:1 potato (b))
7. Sole maize
8. Sole potato

Data measurements and collected

Mean productivity of potato tuber per unit area (ton/ha), maize gain yield in per unit area (ton/ha) and competition indices were collected during the experimental years. The land use efficiency and the competition indices were calculated in the following equations:

Land equivalent ratio (LER): LER is used, as the criterion for mixed stand advantage. In particular, LER indicates the efficiency of intercropping for using the resources of the environment compared with monocropping [14]. The value of unity is the critical value. When the LER is greater than one, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures [15]. It is an indicator of complementarity. The LER was calculated as [16].

LER=(YAB/YAA)+(YBA/YBB) (1)

Where;

YAB=yield of crop A (maize) when intercropped with crop B (potato)

YBA=Yield of crop B (potato) when intercropped with crop A (maize)

YAA=Yield from sole planted crop A (maize)

YBB=Yield from sole planted crop B (potato)

Area time equivalent ratio (ATER): ATER provides more realistic comparison of the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping systems than LER. ATER was calculated by formula developed by Hiebsch [17]:

$$ATER = \frac{(RYa \times Ta) + (RYb \times Tb)}{T} \quad (2)$$

Where;

RYa=Relative yield of component A (maize) in mixture

Ta=duration (in days) of component A (maize)

RYb=Relative yield of component species B (potato) in mixture

Tb=duration (in days) of component B (potato)

T=Total duration of the intercropping system (in days)

The interpretation of ATER involves that ATER>1 implies yield advantage;

ATER=one effect of no effect of intercropping; ATER<1 shows yield disadvantages.

Competitive ratio (CR): Competitive ratio is used to assess competition between different species. The CR gives a better measure of competitive ability of the crops [18]. The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown. It is indicators of competitiveness. The CR was calculated according to the following formula:

CR=LER maize−LER potato (3)

Where LER maize and LER potato were the first (maize) and second (potato) component crops, respectively.CR > 1, indicate the first crop is competitor, while values < 1 implicates the second component crop is profusely suppressed the first crop.

Effective Monetary advantage index (EMAI): It was also calculated to give some economic evaluation of intercropping as compared to sole cropping. The effective monetary advantage index (EMAI) was calculated by the formula developed by Willey RW [19]:

EMAI=Value of combined intercropped yield × (LER-1)/LER (4)

Value of combined intercrops in each cropping system was the lowest prevailing market prices of each component crop in Ethiopian Birr per kg at the time of experiment. The lowest average price at combolcha district, South Wollo after harvest of crops was 5.40 birr/kg for maize in December and 6.00 birr/kg for potato in November. The higher the MAI value the more profitable is the cropping system [20].

Income equivalent ratio (IER): IER is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity. Because income is a function of both yield and crop price, even if the agronomic response is consistent, IER for intercrops may vary in different years as crop prices fluctuate. LER (or IER) can be determined for systems involving more than two crops by summing the intercrop to sole crop yield (or net income) ratios of each crop included in the intercropping system. To calculate the IER market price or gross income (GI) obtained from intercropping a hectare of land were used. It was calculated by the formula developed by Ghaffarzadeh M [21]:

$$IER = \frac{\text{GI/ha of intercropped maize + GI/ha of intercropped potato}}{\text{GI/ha of sole cropped maize GI/ha of sole cropped potato}} \quad (5)$$

Data analysis

Data were statistically subjected to analysis of variance (ANOVA) using JMP-5 software [22]. For maize grain yield, potato tuber yield and for each completion indices (LER, ATER, CR, MAI and IER) combined analyses of variance were performed. In all comparisons, the level of significance was set at α=0.05. Mean comparison for the treatments were computed using each pair Tukey-HSD test for parameters found to be significantly different at a given level of significant.

Results and Discussion

Maize productivity

The present study indicated that intercropping in different spatial arrangement significantly affect grain yield of maize (P<0.01).The highest mean maize grain yield was recorded in sole cropped as compared to all intercropping systems but on par with 1 maize:1 potato arrangement. The lowest mean maize grain yield was obtained at 1 maize: 2 potatoes (a) arrangement due to low plant population per unit area. Clearly, Table 1 showed a decrease in mean maize productivity (5-60%) under intercropping system compared to the sole cropped maize (4.3 ton/ha), but according to the intercropping arrangements, we found that 1 maize:1 potato arrangement (4.1 ton/ha) have significantly gave highest mean grain yield as compared to other intercropping arrangements probably linked to its high plants density, those results agree with Yilmaz et al. [23] and Saddam Aref Al-Dalain [1]. When comparing the reduction of productivity of both crops under intercropping system, the reduction in potato 5.6-67% is higher than that in maize 5-60%. This difference is possibly attributed to the great competition feature of maize plants, which allows it to intercept more light and benefit from CO_2 gas resulting from potato respiration [1]. Similar results were done by Saddam Aref Al-Dalain [1].

Potato productivity

This study presented in Table 1 showed intercropping maize-potato in different spatial arrangement significantly affect potato tuber yield (P<0.01). There was a significant increase in productivity of sole cropped potato (24.8 ton/ha) compared with the intercropped (8-23.4 t/ha). The lowest potato mean tuber yield was obtained at 2 maize:1 potato (b) arrangement due to low plant population per unit area. The reduction ratio of potato productivity in 2 maize:1 potato (b) is 66% compared to the sole cropped potato. A study by Sharaiha et al. [24] and Saddam Aref Al-Dalain [1] confirmed this result by indicating to the potato productivity, which have reduced 61%, 53% when it was intercropped with maize plants, compared to the sole cropped potato, this reduction is related to the low solar radiation intercepted by potato plants and its small leaf area.

The combined mean data presented in Table 1, there is a advantage of 1 maize:1 potato amongst other intercropping treatments according to the productivity of potato plants, which reached 23.4 ton/ha, compared with 8.2 ton/ha in 2 maize:1 potato (b) and this significant increase in the former treatment is attributed to the decreased qualitative inter and intra competition between potato and maize; and potato plants, which resulted from low density of maize plants in unit area and potato planted in 30 cm intra row spacing that allowed potato plants to get a greater domain, which is needed for large biological activity compared with potato under other intercropping arrangements, were there was a high plant density of maize plants and narrow plant intra row spacing. So, low density of maize plants in the unit area planted in greater intra row spacing resulted in a bigger tuber size, attributed to carbon allocation to potato tubers by its leaves, those results agree with study of Begum et al. [25] and Saddam Aref Al-Dalain, et al. [1], which indicated to the reduction of potato productivity when intercropped maize.

Treatment and statistics	Yield (t/ha)					
	Maize			Potato		
	2011	2012	Combined	2011	2012	Combined
1 maize:1 potato	4.1^a	41.0^a	4.1^a	23.3^b	23.5^b.	23.4^b
2 maize:2 potato	2.1^c	20.6^{bc}	2.1^{cd}	12.4^d	12.3^d	12.3^d
1 maize:2 potato (a)	1.6^e	17.2^c	1.7^e	16.7^c	16.7^c	16.7^c
2 maize:1 potato (a)	2.6^b	25.0^b	2.5^b	8.7^e	8.8^e	8.7^e
1 maize:2 potato (b)	1.9^d	18.0^c	1.8^{de}	16.7^c	16.6^c	16.6^c
2 maize:1 potato (b)	2.3^b	22.7^b	2.3^c	8.2^f	8.2.	8.2^f
Sole maize	4.2^a	42.3^a	4.3^a	-	-	-
Sole potato	-	-	-	24.7^a	24.8^a	24.8^a
LSD (5%)	**	*	**	**	*	**
CV (%)	3.26	7.24	4.68	0.94	1.50	1.26

Table 1: Maize grain yield (t/ha) and potato tuber yield (t/ha) for maize–potato intercrops in different spatial agreements at combolcha collage of technical and vocational training (TVET) research farm,

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South Wollo for the period of two growing seasons of 2010 and 2011. Notes: Values (means) connected by different superscript letters are significantly different within columns according to Tukey-HSD tests.

Competition indices

Plant relative yield (PRY): PRY were significantly (P<0.01) influenced by intercropping arraignments (Table 2). The present experiment showed that except partial LER of maize in 1 maize:1 potato arrangement all partial LER of maize and potato in all combination arrangements were lower than sole cropped of each crop species (1.00). Within the intercropping arrangements, the combined highest partial LER of maize (0.96) and potato (0.94) were recorded in 1 maize:1 potato arrangement, while the lowest were recorded in 1 maize: 2 potato (a) (0.39)and 2 maize:1 potato (b) arrangements(0.33), respectively (Table 2). A comparison of the data presented in Table 2 also show that partial LER of maize were higher than partial LER of potato in all intercropping arrangements probably due to efficient utilization of nutrients and light.

On the other hand, the partial LER of maize in maize-potato intercropping arraignments were higher than 0.5 at 1 maize:1 potato (0.96), 2 maize:1 potato (a) (0.59) and 2 maize:1 potato (b) (0.54) which indicates that there was an advantage for maize and a disadvantage for potato in these intercropping arrangements. On the other hand the partial LER of potato in maize-potato intercropping arraignments were higher than 0.5 at 1 maize:1 potato (0.94), 1 maize: 2 potato (a) (0.67) and 1 maize: 2 potato (b) (0.67) which indicates that there was an advantage for potato and a disadvantage for maize in these intercropping arrangements.

Treatment and statistics	Plant relative yield (PRY)					
	PRYMaize			PRYPotato		
	2011	2012	Combined	2011	2012	Combined
1 maize:1 potato	0.97^{b}	0.96^{a}	0.96^{a}	0.94^{b}	0.94^{b}	0.94^{b}
2 maize:2 potato	0.49^{c}	0.48^{b}c	0.48^{cd}	0.50^{d}	0.49^{d}	0.49^{d}
1 maize:2 potato (a)	0.38^{e}	0.41^{c}	0.39^{e}	0.68^{c}	0.67^{c}	0.67^{c}
2 maize:1 potato (a)	0.61^{b}	0.59^{b}	0.59^{b}	0.35^{e}	0.35^{e}	0.35^{e}
1 maize:2 potato (b)	0.45^{d}	0.42^{c}	0.43d^{e}	0.67^{c}	0.66^{c}	0.67^{c}
2 maize:1 potato (b)	0.54^{b}	0.53^{b}	0.54^{c}	0.33^{f}	0.33^{e}	0.33^{f}
Sole maize	1.00^{a}	1.00^{a}	1.00^{a}	-	-	-
Sole potato	-		-	1.00^{a}	0.99^{a}	0.99^{a}
LSD (5%)	**	*	*	**	**	*
CV (%)	3.16	5.86	4.68	0.93	1.50	12.69

Table 2: Plant relative yield for maize–potato intercrops in different spatial agreements at combolcha collage of technical and vocational training (TVET) research farm, South Wollo for the period of two growing seasons of 2010 and 2011. Notes: Values (means) connected by different superscript letters are significantly different within columns according to Tukey-HSD tests. PRY: Plant relative yield.

Total land equivalent ratio (LER): In assessments of crop productivity of sole cropping systems, a useful expression is mass yield (mass per unit area). However, in intercropping systems, direct comparison is difficult because products are different for the different plant species growing on one piece of land [4]. In this case, crop productivity should be evaluated using a common unit. A widely used method is the land equivalent ratio (LER) [4]. Total LER were significantly (P<0.01) influenced by intercropping arraignments (Table 2). Total LER was significantly different from 1.00 in 1 maize:1 potato (1.91), 1 maize: 2 potatoes (b) (1.11) and 1 maize:2 potato (a) (1.06) intercropping arrangements, which shows an advantage from those intercropping arrangements over pure stands in maize-potato combinations in terms of the use of environmental resources for plant growth [14]. The combined yield advantage in terms of total LER indices was greatest in the cases of 1 maize:1 potato intercropping arrangement (1.91) followed by 1 maize: 2 potatoes (b) (1.11) intercropping arrangement (Table 3). This indicates that 91.0% (0.91 ha) and 11.0% (0.11 ha) more area would be required by a sole cropping system to equal the yield of intercropping system. On the other hand, total LERs below 1.00 were found in 2 maize:2 potato , 2 maize:1 potato (a) and 2 maize:1 potato (b), which gave a disadvantage of these intercropping arrangements over pure stands (Table 3). This result was in agreement with Ghosh et al. [20], who reported that common vetch–barley and common vetch-triticale mixtures shows a disadvantage over pure stands.

Area time equivalent ratio (ATER): LER doesn't consider the duration of the crops in the field and it is based on the harvested products, and not on desired yield proportion of the component crops. Moreover, the choice of sole cropped yield for standardizing mixture yield in the estimation of LER is not clear [19]. Therefore, area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of different intercropping systems [26].

The data presented in Table 3 showed that ATER were significantly (P<0.01) influenced by intercropping arrangements. In all maize-potato intercropping arrangements, the ATER values were lesser than

LER values (Table 3) indicating the over estimation of resource utilization perhaps due to the wide variations in the maturity periods of the crops of which maize stayed longer on the land and had enough time to compensate for the potato competition. ATER is free from problems of over estimation of resource utilization contrary to LER. ATER values showed an advantage of 75.0% in 1 maize:1 potato (Table 3). This could be due to the reason that one to one maize-potato intercropping arrangement planted in the same inter and intra row spacing gave compatible more efficient total resource exploitation and greater overall production than sole crops and the remaining intercropping arraignments. Whereas, 2 maize: 2 potato (0.90), 1 maize: 2 potato (a) (0.95), 2 maize:1 potato (a) (0.89), 1 maize: 2 potato (b) (0.99) and 2 maize:1 potato (b) (0.81) intercropping arrangements showed values less than 1.00 (Table 3), thus indicated the disadvantage. Lupine-barely intercropping resulted in maximum disadvantage at 25:100 seeding ratio (61%) [6].

Treatment and statistics	LER Total			ATER		
	2011	2012	Combined	2011	2012	Combined
1 maize:1 potato	1.91^{a}	1.91^{a}	1.91^{a}	1.75^{a}	1.75^{a}	1.75^{a}
2 maize:2 potato	0.99^{d}	0.98^{cd}	0.98^{c}	0.90^{c}	0.90^{bcd}	0.90^{cd}
1 maize:2 potato (a)	1.05^{c}	1.07^{bc}	1.06^{b}	0.94^{c}	0.96^{bc}	0.95^{bc}
2 maize:1 potato (a)	0.96^{d}	0.94^{de}	0.95^{c}	0.90^{c}	0.88^{cd}	0.89^{d}
1 maize:2 potato (b)	1.12^{b}	1.09^{b}	1.11^{b}	1.01^{b}	0.98^{bc}	0.99^{b}
2 maize:1 potato (b)	0.88^{e}	0.86^{e}	0.87^{d}	0.82^{d}	0.81^{d}	0.81^{e}
Sole maize	1.00^{d}	1.00^{bcd}	1.00^{c}	1.00^{b}	1.00^{b}	1.00^{a}
Sole potato	1.00^{d}	0.99^{bcd}	0.99^{c}	0.83^{d}	0.83^{d}	0.83^{e}
LSD (5%)	**	**	**	**	*	*
CV (%)	16.15	3.24	2.55	7.84	3.49	2.77

Table 3: Land equivalent ratio and Area time equivalent ratio for maize–potato intercrops in different spatial agreements at combolcha collage of technical and vocational training (TVET) research farm, South Wollo for the period of two growing seasons of 2010 and 2011. Notes: Values (means) connected by different superscript letters are significantly different within columns according to Tukey-HSD tests. LER: Land equivalent ratio and ATER: Area time equivalent ratio.

Effective monitory advantage index (EMAI): Substantial agronomic advantages from intercropping do not always ensure an economic advantage and there is a need for some economic evolutions and absolute yield comparisons of intercropping systems [27]. Thus, a more satisfactory use of Effective monitory values would probably be to calculate the absolute value of the genuine yield advantage [19]. Accordingly, Effective monitory advantage index (EMAI) was calculated by multiplying the respective yields of the component crops by their lowest market prices during the experiment and divided by respective LER. Intercropping advantage values indicates the disadvantage of the system as the EMAI values were in negative. On the other hand monetary advantage index values were positive which showed a definite yield advantage in intercropping compared to sole cropping [28]. It is an indicator of the economic feasibility of intercropping systems as compared to sole cropping [26].

The studied data presented in Table 4 showed that EMAI were significantly (P<0.01) influenced by intercropping arraignments. The EMAI values were positive under three intercropping systems in the present study, i.e. in 1 maize:1 potato (66970), 1 maize: 2 potato (a) (6251), and 1 maize: 2 potato (b) (9769) intercropping arraignments (Table 4), which shows a definite yield advantage compared with the respective sole cropping systems and other intercropping arraignments tested in this study. EMAI values in 2 maize: 2 potato (-1107), 2 maize:1 potato (a), (-2699) 2 maize:1 potato (b) and (-7355) intercropping arraignments were found highly negative as compared to all pure stands due to very low LER caused by sever reduction in potato yield. The result was in corroborates with Dhima et al. [29], who reported that Vetch-barely intercropping in different seeding ratios gave negative EMAI as compared to sole cropping. Similarly, EMAI values in all lupine-barley combinations were found highly negative as compared to all pure stands due to very low LER caused by sever reduction in lupine yield [6]. Maximum negative value in the latter intercropping arraignments implying unsuitability arrangement showed an economic disadvantage. The combined maximum positive EMAI values in the former intercropping arraignments indicated that these intercropping arrangements had the highest economic advantage and implying the suitability of intercropping arraignments. A plausible explanation for the later might be the better utilization of resources between maize-potato intercropping arraignments. Similarly, Ghosh et al. [20] found that when the LER were higher there is also significant economic benefit expressed with higher EMAI.

Competitive ratio (CR): Competitive ratio (CR) is only used as a measure of intercrop competition (inter-specific competition) [29]. CR of maize, potato and total were significantly (P<0.01) influenced by intercropping arrangements (Table 4). The data presented in Table 3 clearly showed that the CR values for all crops in all intercropping arrangements were less than one indicating both crops are equally Competitive. However, in 1 maize:1 potato (0.02), 2 maize:1 potato (a) (0.25), 2 maize:1 potato (b) (0.21) intercropping arrangements maize had positive competitive ratios, indicating that maize was more competitive potato (Table 4). This could probably occur through the creation of shade [30]. However, in all other intercropping arrangements (2 maize: 2 potato (-0.01), 1 maize: 2 potato (a) (-0.28), 1 maize: 2 potato (b) (-0.23)) the values of CR for maize were negative indicating the dominance of potato over maize Table 3). This probably due to early potato dominance did appear to suppress maize growth. This corroborates with Trydeman et al. [31] and Bantie et al. [6] who stated that barley (early harvested) was dominant over lupine (long duration to mature).

Treatment and statistics	CR (LERMaize-LERPotato)			EMAI		
	2011	2012	Combined	2011	2012	Combined
1 maize:1 potato	0.0241c	0.02c	0.02c	66618a	67323a	66970a
2 maize:2 potato	-0.0139c	-0.01c	-0.01c	-1039d	-1176cd	-1107c
1 maize:2 potato (a)	-0.2965e	-0.26d	-0.28d	5234c	7269b	6251b

2 maize:1 potato (a)	0.2569b	0.24	0.25b	-2153 d	-3245	-2699c
1 maize:2 potato (b)	-0.2240d	-0.24d	-0.23d	11113 b	8425bc d	9769b
2 maize:1 potato (b)	0.2147b	0.20b	0.21b	-6961 e	-7749d	-7355d
Sole maize	1.0000a	1.0a	1.00a	0d	0c	0c
Sole potato	-1.0000f	-0.99e	-0.99e	0d	-20c	-10c
LSD (5%)	*	*	**	**	*	*
CV (%)	2.18	20.31	18.62	13.81	28.84	22.72

Table 4: Competitive ratio and Effective monitory advantage index for maize–potato intercrops in different spatial agreements at combolcha collage of technical and vocational training (TVET) research farm, South Wollo for the period of two growing seasons of 2010 and 2011. Notes: Values (means) connected by different superscript letters are significantly different within columns according to Tukey-HSD tests. CR: Competitive ratio and EMAI: Effective monitory advantage index.

Income equivalent ratio (IER): Income equivalent ratio for maize, potato and total were significantly (P<0.01) influenced by intercropping arraignments (Table 5). Income equivalent ratio for maize, potato and total were the same result with the plant relative yields of maize and potato presented in Table 2. Income equivalency ratio (IER) is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity [32]. Within the intercropping arrangements, the combined highest partial IER of maize (0.96) and potato (0.94) were recorded in 1 maize:1 potato arrangement, while the lowest were recorded in 1 maize: 2 potato (a) (0.39)and 2 maize:1 potato (b) (0.33) arrangements, respectively (Table 5). On the other hand IER was significantly different from 1.00 in 1 maize:1 potato (1.91), 1 maize: 2 potatoes (b) (1.11) and 1 maize:2 potato (a) (1.06) intercropping arrangements, which shows an advantage from those intercropping arrangements over pure stands in maize-potato combinations in terms of the use of environmental resources for plant growth [14]. The combined yield advantage in terms of total IER indices was greatest in the cases of 1 maize:1 potato intercropping arrangement (1.91) followed by 1 maize: 2 potatoes (b) (1.11) intercropping arrangement (Table 5). On the other hand, IER s below 1.00 were found in 2 maize:2 potato, 2 maize:1 potato (a) and 2 maize:1 potato (b), which gave a disadvantage of these intercropping arrangements over pure stands (Table 5).

Treatment and statistics	Income equivalent ratio								
	IER Maize			IER Potato			IER		
	2011	2012	Combined	2011	2012	Combined	2011	2012	Combined
1 maize:1 potato	0.97^{a}	0.96^{a}	0.96^{a}	0.94^{b}	0.94^{b}	0.94^{b}	1.91^{a}	1.91^{a}	1.91^{a}
2 maize:2 potato	0.49^{d}	0.48^{bcd}	0.48^{cd}	0.50^{d}	0.49^{d}	0.49^{d}	0.99^{d}	0.98^{bc}	0.98^{c}
1 maize:2 potato (a)	0.38^{e}	0.40^{d}	0.39^{e}	0.67^{c}	0.67^{c}	0.67^{c}	1.05^{c}	1.07^{b}	1.06^{b}
2 maize:1 potato (a)	0.61^{b}	0.59^{b}	0.59^{b}	0.35^{e}	0.35^{e}	0.35^{e}	0.96^{d}	0.94^{c}	0.95^{c}
1 maize:2 potato (b)	0.45^{d}	0.42^{cd}	0.44^{de}	0.67^{c}	0.66^{c}	0.67^{c}	1.12^{b}	1.09^{b}	1.11^{b}
2 maize:1 potato (b)	0.54^{c}	0.53^{bc}	0.54^{c}	0.33^{f}	0.32^{e}	0.33^{f}	0.88^{e}	0.86^{c}	0.87^{d}
Sole maize	1.00^{a}	1.00^{a}	1.00^{a}	-	-		-	-	-
Sole potato	-	-	-	1.00^{a}	1.00^{a}	1.00^{a}	-	-	-
LSD (5%)	**	**	*	**	*	*	**	*	*
CV (%)	2.84	6.34	4.76	2.52	2.10	1.26	1.91	3.27	2.95

Table 5: Income equivalent ratio for maize–potato intercrops in different spatial agreements at combolcha collage of technical and vocational training (TVET) research farm, South Wollo for the period of two growing seasons of 2010 and 2011. Notes: Values (means) connected by different superscript letters are significantly different within columns according to Tukey-HSD tests. EIR: Income equivalent ratio.

Conclusion

The combined yield advantages in terms of total land equivalent ratio (LER) and Income equivalent ratio (IER) indices were greatest in the cases of 1 maize:1 potato followed by 1 maize:2 potato (b) intercropping arrangement. Area time equivalent ratio (ATER) values showed an advantage of 75.0% only in 1 maize:1 potato. Effective Monetary advantage (EMAI) index was highest in 1 maize:2 potato (b)followed by 1 maize:1 potato intercropping arraignments. However, Competitive ratio (CR) values for all crops in all intercropping arrangements were less than one indicating both crops are equally competitive. Based on the this findings, 1 maize:1 potato followed by 1 maize:2 potato (b) intercropping arrangement gave the highest PRY, LER,ATER, IER and EMAI; and lowest CR value and in turn achieve higher productivity rates of the two crops, which lead to favorably recommend the use and utilization of this system in south wollo. This project was conducted for two years only at research farm due to lack of budget and hence this research should be repeated on on-farm in different agro ecology of the country under different spatial arrangement

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