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Estimation of Yield Advantage and Competitiveness of Onion-Rosemary Intercropping over Sole Cropping at Wondo Genet, Southern Ethiopia

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ABSTRACT

Different cropping system and planting patterns of onion and rosemary evaluated to estimate yield advantage and their competitiveness during 2013-14 and 2014-15 growing seasons under irrigated condition at wondo genet Sidama zone, Southern Ethiopia. The experiment comprised of six treatments: sole Onion (250,000 plants ha-1), sole Rosemary (83,333plants ha-1) and four onion-rosemary intercropping mix proportion: 100 onion: 80 rosemary, 100 onion: 60 rosemary, 100 onion: 40 rosemary and 100 onion: 20 rosemary, using randomized complete block design with three replications. Analysis of variance revealed that; intercropping of onion with different population densities of rosemary significantly affected dry bulb yield; highest dry bulb yield was recorded at solitary cropping than that of intercropped. Similarly; essential oil yield of rosemary significantly influenced by cropping system; highest essential oil yield obtained in sole planted than intercropped. The highest value of land equivalent ratio (1.52), land equivalent coefficient (0.57) and relative crowding coefficient (6.07) obtained when onion intercropped with 80 % rosemary population density. However, positive values of actual yield loss and maximum intercropping advantage obtained in treatments where onion intercropped with rosemary at 20 and 40 % population density. Generally, these finding suggest that intercropping of onion with rosemary at 80 % population density enhanced yield advantage and Competitiveness as indicated by higher land equivalent ratio and relative crowding coefficient. Therefore, the inclusion of onion with 80% a rosemary population density elevated yield advantage and competitiveness over sole planted crop per unit area as indicated by higher LER and relative crowding coefficient.

Keywords: Competitiveness, Intercropping, Onion, sole, Rosemary, Yield Advantage

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Introduction

Agriculture remains vital for Ethiopia as over 80% of population directly or indirectly depends on some form of farming for their nourishment and livelihoods (CSA, 2013). One of the main problems associated with the Ethiopian agricultural system is the low size of cultivated land per household level. This led to an increase need to maximum land usage to enhance farmer's income. Thus, enhancing agricultural production per unit area is the only way to increase agricultural production through more efficient use of natural resources with minimal impact on the environment in order to meet the growing population demands (Hobbs *et al.*, 2008). Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of humanity, and is in balance with the environment (Gruhn et al., 2000).

Multiple cropping is one of the best ways of increasing production per unit area by growing two crops of dissimilar growth habit in the same field with little intercrop competition. Intercropping is one of the multiple cropping system; it is the simultaneous growing of two or more crops in the same field at the same time by utilizing growth resources such as soil, water, nutrients and solar radiation more efficiently (Rana et al., 2013). Intercropping offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield and thus providing diversified needs of small farmers, stability of yield over different seasons, better control of weeds, insect pests and diseases as well as control of soil erosion (Emam, 2003).

Numerous research finding pointed out intercropping gave increased crop production compared to sole crops; might be due to enhanced resources utilization (Szumigalski and Van-Acker, 2008; Zhang and Li, 2003). Moreover, intercropping provides a balanced diet, minimizes risks of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability and provides higher returns (Dapaah *et al*., 2003). Currently, the use of intercropping by smallholder farmers is interestingly increasing in low-input crop production systems and a common practice that dates back to ancient civilization (Dahmardeh M, 2009) in the tropics and rain-fed areas of the world (Dhima, K.V, 2007).

When two crops planted together, intra and/or inter specific competition or facilitation between plants may occur (Zhang and Li, 2003). Islam, M.N (2002) reported that greater productivity in intercropping system commonly achieved by minimizing inter-specific competition and maximizing complementary use of growth resources. Therefore, choice of intercropped crops is critical since the selected crops must be complement each other rather compete with each other. Previous studies showed that mixtures of cereals and legumes produce higher grain yields than either crop grown alone (Dapaah HK, 2003).

Competition among mixture is thought to be a major aspect-affecting yield as compared with sole cropping of cereals (Ndakidemi, 2006). Different researchers employed various measures of the efficiency of intercropping systems relative to sole cropping. A number of indices such as land equivalent ratio, area time equivalent ratio, relative crowding coefficient, competitive ratio, aggressivity, actual yield loss, monetary advantage, and intercropping advantage have been proposed to describe competition within and economic advantages of intercropping systems (Ghosh PK, 2004; Mazaheri D, et al., 2006; Yilmaz S, 2007).

Smallholder farmers in Ethiopia practice cereal-legumes intercropping essentially to maximize land and labor productivity. Moreover, in cereal-legume mixtures, legumes improve soil nitrogen and thereby cereal may benefit from the fixed nitrogen in the current cropping season (Adu-Gyamfi *et al*., 2007; Undies *et al*., 2012). Earlier studies on intercropping of onion, garlic, coriander, green gram, black gram and chilli with other crops revealed that encouraging results over sole planted (Kadali VG, et al., 1989). However, onion-rosemary intercropping in respective of yield advantage and their competitiveness not yet done, mainly in our condition. Therefore, the present study carried out to evaluate the effects of cropping systems and planting patterns on yield advantage and competitiveness of onion-rosemary intercropping over sole cropped using different competitive indices.

Material and Method

A field study was carried out at Wondo Genet Agricultural Research center to estimate the yield advantages, competitiveness and economic benefits of onion based rosemary intercropping for two consecutive years on sandy clay loam with soil pH of 5.91, which was slightly acidic. Wondo Genet Agricultural Research Center is geographically located at 07° 19.1' North latitude, 38° 30’ East longitude and an altitude of 1780m.a.s.l.

The experimental design was randomized complete block design (RCBD) in additive series with six (6) treatments and four (4) replications. Plot size was 3*4 m^2. Onion was the principal crop and spaced at a distance (10*40) cm^2 and the plant population was 250000 ha^{-1}.The sole rosemary population was taken as 83333 plant ha^{-1} and was spaced at a distance of 30*40 cm^2 and also four rosemary population densities 80%, 60%, 40% and 20% were used as a companion crop. In every alternate row of onion with a plant-to-plant distance were 37.5, 50, 75, and 150 cm for 80, 60, 40 and 20% rosemary population, respectively.

Adama red onion variety used as test crop; seedlings were raised in nursery and transplanted to the actual field, forty-five days after seed sown in both seasons. Likewise, rosemary seedlings raised in nursery and transplanted to the actual field. Regarding to fertilization, recommended dose of phosphorus containing fertilizer was applied at a level of 100 kg DAP ha^{-1} during planting of the main crop. However, nitrogen-containing Urea fertilizer applied at a level of 50 kg ha^{-1} in split form, half of the recommended at planting and the remaining half applied before flowering of the main crop, respectively. All other agronomic practices like hoeing, weeding, etc., were kept normal for all the treatments.

Yield and yield components of the two crops collected based on the recommended harvesting seasons for each crop. Essential oil yields analysis was done using gas chromatography-mass spectrophotometer or modified Clevenger collector apparatus. The local market price of onion and essential oil yield of rosemary were 8 birr/kg and 20 birr/kg, respectively during the two consecutive harvesting seasons.

The yield advantage of different intercropping systems over the mono cropping of the individual crops were determined in terms of total yield equivalent, land equivalent ratio, land equivalent coefficient and Area time equivalent ratio (ATER).

Land equivalent ratio (LER) which verifies the effectiveness of intercropping over sole cropping in using environmental resources.

$$TLER = PLER\ onion + PLER\ rosemary$$

$$PLER\ onion = YIO/YO$$

$$PLER\ rosemary = YIrose/Yrose$$

Where TLER, total land equivalent ratio; PLER onion, Partial land equivalent ratio of onion; PLER rosemary, Partial land equivalent ratio of rosemary; YIO, onion yield in intercropping system; YO, onion yield in sole planted; YI rose, rosemary yield in intercropping system; Y rose, rosemary yield in sole planted.

Using the following formula the Area Time Equivalent Ratio (ATER) computed:-

$$ATER = \frac{\{(Li * ti) + (Lj * tj)\}}{T}$$

Where Li and *Lj* are relative yields or partial LERs of component crops i for onion and j for rosemary, *ti* and *tj* are the durations (days) for crops i and j, and *T* is the duration (days) of the whole intercrop system.

Land Equivalent Coefficient (LEC) calculated using the following formula:-

$$LEC = PLER\ onion * PLER\ rose$$

Competition functions: The competitive functions of the two crop computed in terms of relative crowding coefficient, aggressivity and competitive ratio.

Relative crowding coefficient (RCC)

Relative crowding coefficient (K) which measures the dominance of one species over the other in a mixture. As proposed by Dewit (1960) relative crowding coefficient (K) calculated as follow:

$$\boldsymbol{K = K\ onion * K\ rose}$$

$$Konion = \frac{[YIO * ZI\ rose]}{(YO - YIO) * ZIO}$$

$$K\ rose = \frac{[YIrose * ZIO]}{(Yrose - YIrose) * ZIrose}$$

Where K, total relative crowding coefficient; K-onion, relative crowding coefficient of onion; K-rose, relative crowding coefficient of rosemary; YIO, onion yield in intercropping system; YO, onion yield in sole planted; YI rose, rosemary yield in intercropping system; Y rose, rosemary yield in sole planted; ZI rose, proportion of rosemary in intercropping system; ZIO, proportion of onion in intercropping system. When the value of K is greater than 1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage;

Aggressivity (A) used to determine the competitive relationship between the two crops in a mixture and calculated using the following formula:

$$AO = \left\{\frac{YIO}{YO} * ZIO\right\} - \left\{\frac{YIrose}{Yrose} * ZIrose\right\}$$

$$Arose = \left\{\frac{YIrose}{Yrose} * ZIrose\right\} - \left\{\frac{YIO}{YO} * ZIO\right\}$$

Where AO, Aggressivity of onion; Arose, Aggressivity of rosemary; YIO, onion yield in intercropping system; YO, onion yield in sole planted; YI rose, rosemary yield in intercropping system; Y rose, rosemary yield in sole planted; ZI rose, proportion of rosemary in intercropping system; ZIO, proportion of onion in intercropping system.

Competitive ratio (CR):- The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops on which they initially sown. Using the following formula CR index was calculated:

$$CRO = \left(\frac{LERonion}{LERrose}\right) * \left(\frac{ZIrose}{ZIO}\right)$$

$$CRrose = \left(\frac{LERrose}{LERonion}\right) * \left(\frac{ZIonio}{ZIrose}\right)$$

Where CRO, onion competitive ratio; CRrose, rosemary competitive ratio; LERonion, partial land equivalent ratio of onion; LERrose, partial land equivalent ratio of rosemary; ZI rose, proportion of rosemary in intercropping system; ZIO, onion proportion in intercropping system.

Actual yield loss (AYL) index, which gave more accurate information about the competition than the other indices between components of intercropping system. The AYL is the proportionate yield loss of intercrops compared to sole crop.

$$AYL = AYLonion + AYLrose$$

$$AYLonion = \left[\frac{\frac{YIO}{ZIO}}{\frac{YO}{ZO}}\right\} - 1$$

$$AYLrose = \left[\frac{\frac{YIrose}{ZIrose}}{\frac{Yrose}{Zrose}}\right\} - 1$$

Where AYL onion, Actual yield loss of onion; AYL rose, Actual yield loss of rosemary; YIO, onion yield in intercropping system; YO, onion yield in sole planted; YI rose, rosemary yield in intercropping system; Y rose, rosemary yield in sole planted; ZI rose, proportion of rosemary in intercropping system; ZIO, onion proportion in intercropping system.

Intercropping advantage (IA) was estimated as IA = AYL x Price of dry yield of onion and essential oil yield of rosemary (the current price of dry bulb yield of onion and essential oil yield of rosemary are 8 and 20 Ethiopian Birr per kg, respectively. Finally, the collected data were statistically analyzed using SAS computer software version 9.3 English and the significance difference between any two treatments means tested by least significant difference (LSD) at 5% probability level.

Result and Discussion

Pooled mean analysis of variance revealed that dry bulb yield of onion significantly (P<0.05) influenced by cropping systems. Sole planted onion gave highest dry bulb yield, which was statically at par with onion intercropped with 60 %, 40 % and 20 % rosemary, respectively. However, onion intercropped with 80 % rosemary population density showed lowest dry bulb yield. This result suggested that as population densities of companion crop decreased the dry bulb yield of onion increased. The yield increment might be associated with less growth resource (light, water, nutrients and so on) competition by the companion crop while its population density decreased. In agreement, Talukder et al. (2015) reported that onion intercropped with 20 % coriander gave the maximum onion equivalent yield. Kadali VG, et al. (1989) also reported that seed yield of onion was higher in monoculture as compared to their corresponding intercropped yield. Marey (2003) also reported that increased population density of the companion crop significantly affected yield of the mail crop.

Likewise, essential oil yield of rosemary was significantly (p<0.05) influenced by cropping system; maximum (164.93 kg/ha) and minimum (46.89 kg/ha) essential oil yield obtained from sole and intercropped treatments, respectively. Concerning to the intercropping patter, essential oil yield of rosemary significantly affected by different levels of intercropping pattern. The highest (113.38 kg/ha) and the lowest (46.89 kg/ha) essential oil yield reduction observed in treatments where onion intercropped with rosemary in 20 % and 80 % population density, respectively. The reduction in essential oil yield as its population density deceased possibly due to the reduced biomass yield. Analogous research finding witnessed on Rose-scented geranium intercropped with vegetables (Rajesh et al., 2011) and Rose-scented geranium intercropping with corn mint (Rajeswara Rao, 2002).

Pooled mean analysis result showed that, partial land equivalent ratio of onion was significantly (P<0.05) influenced by different intercropping patters; the highest value was recorded at onion intercropped with 20 % rosemary population density. The analysis result revealed that partial land equivalent ratio of the main crop decreased as population density of the companion crop increased. Similarly, partial land equivalent ratio of the companion crop (rosemary) was significantly (P<0.05) affected by the intercropping pattern (Table 1); highest (0.86) and lowest (0.29) partial land equivalent ratio resulted in treatments where onion intercropped with rosemary at 80% and 20% population density, respectively. Unlike, the onion, partial land equivalent ratio of rosemary had shown increasing tends while population density increased. Mariga *et.al*. (2001), reported that a higher partial land equivalent ratio of the companion crop observed at higher population densities of pigeon pea in maize/ pigeon pea intercropping.

Concerning to the total land equivalent ratio, all intercropping patters had higher LER than monoculture, which indicated the superiority of intercropping over monoculture. The highest amount of LER 1.52 obtained in treatment where onion intercropped with rosemary at 80 % population density (Table 1); the obtained result shown that the mono cropping would require 0.52 more unit of land to have the same yield as intercropped. The yield advantage could be due to a possible efficient utilization of growth resources by the intercropped crop over mono cropped (Willey, 1999; Reddy, 2000). This implies that the association of onion and rosemary at this intercropping patter is complementary to each other on growth resource utilization. Similar research investigation were also reported by Rajesware

Rao (2002); Ramkat et al. (2008); Abdul *et al.* (2009); Tolera and Daba (2009); Egbe (2010); Takim (2012) whose reported that superior LER resulted in intercropping over sole cropping of tomato, maize, sorghum, rice, corn mint, faba bean.

Table 1. Dry bulb and Essential oil yields, Land equivalent ratio and Land equivalent coefficient for sole stands and mixture of Onion with Rosemary.

Treatments	Dry bulb and Essential oil yield (Kg/ha)		Land Equivalent ratio (LER)			Land Equivalent coefficient LEC	Area time Equivalent ratio(ATER)
	Onion	Rosemary	PLER-onion	PLER-rosemary	TLER	**LEC**	ATER
Sole onion	11561^{a}	-	-				
Sole rosemary	-	164.93^{a}	-				
100 onion:20%rosemary	10973^{a}	46.89^{e}	0.97^{a}	0.29^{d}	1.26^{b}	0.28^{b}	0.64^{d}
100 onion:40%rosemary	10650^{a}	87.01^{d}	0.95^{a}	0.53^{c}	1.47^{a}	0.52^{a}	0.88^{c}
100 onion:60%rosemary	9071^{ab}	113.38^{c}	0.83^{a}	0.69^{b}	1.49^{a}	0.53^{a}	0.99^{b}
100 onion:80%rosemary	7839^{b}	139.92^{b}	0.60^{b}	0.86^{a}	1.52^{a}	0.57^{a}	1.13^{a}
LSD	1928.1	8.39	0.2	0.06	0.18	0.13	0.11
CV %	14.59	5.42	15.16	6.56	8.09	16.17	7.6

Within columns, means followed by the same letter are not significantly different at P = 0.05.

About the land equivalent coefficient, analysis result depicted that LEC of the intercropping pattern had shown increasing trends with population density of the companion crop; ranging from 0.28 to 0.57, which are superior to the expected productivity coefficient 25%. According to Adetiloye et al. (1983), for a two-crop mixture the minimum expected productivity coefficient should be 25 %; meaning a yield advantage, if land equivalent coefficient (LEC) value was exceeds 0.25. In this particular study, the value of LEC was greater than the critical value 0.25 in all onion-rosemary intercropping pattern and the maximum value (0.57) was obtained in treatment where onion intercropped with rosemary at 80% population density (Table 1). Similarly, Egbe (2005) has reported LEC values greater than the critical in intercropping sorghum with soybean at different spatial arrangements.

Area time equivalent ratio (ATER) also 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. In this study, area time equivalent ratio significantly influenced by intercropping system, highest (1.13) and lowest (0.64) values of ATER obtained in treatments where onion intercropped with rosemary at 80 % and 20 % population density, respectively. Similar to total land equivalent ratio, ATER had shown increasing trends as population density of the companion crop increased.

Relative crowding coefficient (RCC)

According to the analysis result in table 2, rosemary was the dominant crop with higher K value than the onion with lower K value. If the product of RCC of the two specie is equal, less or greater than one it means that the intercropping system has no advantage, disadvantage or advantage, respectively. Accordingly, analysis of variance revealed that relative crowding coefficient of onion was less than one in all intercropping pattern (Table 2). This result expressed that using onion for intercropping purpose with rosemary had disadvantage. However, the relative crowding coefficients of rosemary was greater that unit at 60 and 80% population density, this indicated that making intercropping of rosemary had advantage in terms of competition. Moreover, the relative crowding coefficients of rosemary had have increasing trends while its population density increased, the highest (48.53) and lowest (0.22) RCC values of rosemary were obtained in onion intercropped with rosemary at 80 % and 20 % population density, respectively.

Conversely, the product of relative crowding coefficient of the two component crops was less than one in onion intercropped with rosemary at 20, 40 and 60 % population density respectively, this revealed that making intercropping was no yield advantage of one crop over another and the system had disadvantage. However, the product of relative crowding coefficient was greater than one (6.07) where onion intercropped with rosemary at 80 % population density; this result indicated that adopting this cropping patter had advantage than the others.

Aggressivity

Aggressivity is an important competition function to determine the competitive ability of a crop when grown in association with another crop. An aggressivity value of zero indicated that component crops are equally competitive. For another situation, both crops will have the same numerical value but the sign of the dominant species will be ‘positive’ and that of dominated ‘negative’. The greater the numerical value, the higher is the difference in competitive abilities and the higher the differences between actual and expected yields.

The analyzed data shown in Table 2 revealed that the component crops did not compete equally. The whole intercrop pattern specified both dominated behavior as specified by their negative (-) sign for rosemary crop and dominant performance observed on onion crop as indicated by their positive (+) sign. Aggressivity values of onion was increased as population density of the companion crop decreased; the highest aggressivity value (+91.1) of onion was found in onion intercropped with rosemary at 20 % population density followed by 40 % rosemary (+74.2). On the other hand, the lowest value (-8.77) obtained from onion intercropped with rosemary at 80 % population density; indicated that onion was the least competitive crop at 80 % rosemary intercropping. This result in agreement with those research findings obtained by El-Kafoury et al. (1993); Farghaly et al. (2003); Abou-Elela and Gadallah (2012). Unlike onion, aggressivity value of rosemary increased as its population density increased, which means as its population density increased seemingly aggressivity also increased. The maximum and minimum aggressivity values of rosemary obtained at 80 % and 20 % population densities of rosemary, respectively.

Competitive ratio (CR)

Competitive ratio (CR) is another way to know the degree with which one crop competes with the other crop in the intercrop. It gives better measure of competitive ability of the crops and is advantageous as an index over crowding coefficient and aggressivity (Willey and Rao, 1980). The analyzed result depicted that intercropped onion had lower CRs values in all mixtures as compared with rosemary. The highest (0.72) and the lowest (0.56) CR values of onion obtained in treatment where onion intercropped with rosemary at 20 % and 80 % population density, respectively and decreased gradually as the proportion of the companion crop in the mixture increases. Similarly, its aggressivity also decreased while population density of the companion crop increased. On the other hand, intercropped rosemary had higher

CRs values in all mixtures, the CR values for rosemary increased with an increase in its aggressivity and population density in the mixtures (table 2). Among the different rosemary population densities intercropped with onion, the rosemary proved to be better competitive when grown in 80 % population density.

Table 2. Effects of intercropping pattern on Relative crowding coefficient, Aggressivity and Competitive Ratio in Onion –Rosemary intercropping system during 2014 and 2015.

Treatments	Relative crowding coefficient (K)			Aggressivity (A)		Competitive Ratio (CR)	
	Onion	Rosemary	Total	Onion	Rosemary	Onion	Rosemary
100 onion:20%rosemary	-16.55	0.22	-6.05	91.10	-91.10	0.72	1.46
100 onion:40%rosemary	-4.26	0.77	-3.86	74.20	-74.20	0.71	1.47
100 onion:60%rosemary	-1.71	1.84	-4.2	41.16	-41.16	0.68	1.52
100 onion:80%rosemary	0.395	48.53	6.07	-8.77	8.77	0.56	1.80

Within columns, means followed by the same letter are not significantly different at P = 0.05.

Actual Yield Loss

The actual yield loss (AYL) is the proportionate yield loss of an intercrop compared to sole crop. Banik et al. (2000) reported that actual yield loss (AYL) index could also give more precise information about the competition than the other indices between and within the component crops and the behavior of each species in the intercropping systems, as it based on yield per plant. Partial actual yield loss also represents the proportionate yield loss of each specie grown as intercrops compared to pure stand. The positive or negative values of AYL indicated the advantage or disadvantage of the intercropping when the main aim is to compare yield on a per plant basis.

In all intercropping patter, actual yield loss of onion had negative values ranging from -0.03 to -0.26; compared with pure stand onion yield, the highest (26%) and lowest (3%) yield loss of onion were recorded at onion intercropped with 80 % and 20 % population density of rosemary, respectively. This particular study shown that actual yield loss of the main crop (Onion) increased as population density of the second crop (rosemary) increased. However, the actual yield loss of rosemary had shown positive values in all intercropping pattern indicating a yield gain of 8 % and 45%, respectively, compared to sole rosemary yield. Unlike, the onion, actual yield loss of rosemary did not show increasing trend while its population density increased.

Analysis of variance revealed that total actual yield loss significantly influenced by different intercropping pattern. Positive values of actual yield loss observed in treatments where onion intercropped with rosemary at 20 and 40 % population density (Table 3). Consequently, an AYL positive coefficient indicates the advantage of intercropping over monoculture. In this study, the highest amount of AYL (18 %) obtained in treatment where onion intercropped with rosemary at 80% population density. Mansouri et al. (2013) also reported similar research result he pointed out AYL of the main crop increased as population density of the companion crop increased.

Intercropping Advantage

According to Banik et al. (2000), this index, in addition to expressing the advantage or disadvantage of intercrops, can be an indicator of the economic feasibility of cropping systems. The maximum intercropping advantage obtained in treatment where onion intercropped with rosemary at 20 % population density followed by 40 and 60 % rosemary population densities, respectively. However, the lowest (-0.5) intercropping advantage was obtained in treatment where onion intercropped with rosemary in 80 % population density, indicating that making intercropping at this level of companion crop (rosemary) leads to maximum yield loss of the main crop (onion).

Table 3. Effects of intercropping pattern on Actual Yield Loss and Intercropping Advantage in Onion –Rosemary intercropping system during 2014 and 2015.

Treatments	Actual Yield Loss (AYL)			Intercropping Advantage (IA)		
	Onion	Rosemary	Total	Onion	Rosemary	Total
100 onion:20%rosemary	-0.03	0.45	0.42	-0.25	9.10	8.86[a]
100 onion:40%rosemary	-0.04	0.34	0.29	-0.35	6.73	6.37[a]
100 onion:60%rosemary	-0.17	0.16	-0.01	-1.36	3.21	1.84[b]
100 onion:80%rosemary	-0.26	0.08	-0.18	-2.09	1.59	-0.5[b]

Within columns, means followed by the same letter are not significantly different at P = 0.05.

Conclusion and Recommendation

The present study concluded that intercropping onion with rosemary in different cropping systems and planting patterns might affect yield due to competition between the two crops compared to sole cropping. Highest dry bulb yield and essential oil yield was recorded at solitary cropping than that of intercropped. The land equivalent ratios were higher than one in all intercropping plots indicating an optimum exploitation of the environmental resources. The values of CR, A and K clearly indicated that different cropping patterns significantly influenced the competitive ability of intercrops. The highest value of LER (1.52), LEC (0.57), ATER (1.33) and K (6.07) obtained when onion intercropped with 80 % rosemary population density, the result indicated that adopting this mix-proportion had advantage than the others.

Regardless of aggressivity, except onion intercropped with rosemary at 80 % population density, onion was the dominant species. However, positive values of actual yield loss observed in treatments where onion intercropped with rosemary at 20 and 40 % population density. Similarly, maximum intercropping advantage obtained in treatment where onion intercropped with rosemary at 20 % population density followed by 40 and 60 % rosemary population densities, respectively.

Generally, this research finding suggested that intercropping of onion with rosemary at 80 % population density enhanced yield advantage and Competitiveness as indicated by higher LER and K. Conversely, the result also pointed out intercropped onion with rosemary at 20 % population density revealed positive actual yield loss and maximum intercropping advantage. Therefore, the inclusion of onion with 80% a rosemary population density raised yield advantage and competitiveness over sole planted crop per unit area as indicated by higher LER and relative crowding coefficient.

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