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Intercropping of carrot (Daucus carota L.) with Rosemary (*Rosmarinus officinalis* L.) as Supplementary Income Generation at Wondo Genet, South Ethiopia

Nibret Tadesse Betru

Associate researcher, Wondo Genet Agricultural Research Center, Eiar. P.O.BOX: 198-Shashemene, Ethiopia.
Email: nibrettadesse@gmail.com. MOBILE: +251 913687489 [1]

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Smallholder's farmers have limited landholding in the south region and the area highly populated therefore there is a need to improve land use system and the way to improve their income generation methods through intercropping of companion crops like carrot and rosemary. An experiment was conducted at Wondo Genet Research Center in 2017 and 2018 cropping seasons. The aim of the study was to determine the intercropping ratio of rosemary into a carrot-rosemary based cropping system for additional income generation. The experiment was laid out in randomized complete design using six intercropping ratios; T1= Sole Carrot, T2= Sole Rosemary, T3=100% carrot + 25% Rosemary, T4=100% Carrot+50% Rosemary, T5=100% carrot+75% Rosemary, T6= 100% Maize +100% Rosemary. The two-year result revealed that there was a significant total land equivalent ratio and monetary advantages between the intercropping ratios of rosemary and they were compatible for production. In 2017 and 2018 cropping season significantly higher land equivalent ratio (1.94) and (1.71) were recorded from the intercropping ratio of 100% carrot in 100% rosemary. The lowest land equivalent ratio of total (1.33) and (1.23) were obtained from the intercropping ratio of 100% carrot with 25% rosemary. In 2017 and 2018 cropping season significantly maximum monetary advantage index (171378) and (98768) were recorded from the intercropping ratio of 100% carrot with 25% rosemary. From the result, I found intercropping 25% and 50% of rosemary with 100% carrot gave significantly higher in terms of monetary advantage index. Therefore, for additional income generation for small scale farmers and intensive agriculture system; we recommend an intercropping ratio of rosemary from 25% up to 50% of recommended rosemary population density with carrot would help for additional income generation than mono cropping either of the crops.

Keywords: Intercropping ratio, Carrot, Rosemary, Land Equivalent Ratio and Additional income generation

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INTRODUCTION

Intercropping is the growing of two or more cultivars simultaneously in the same land by utilizing resources such as soil, water, nutrients and solar radiation more efficiently (Rana *et al*., 2014). Nowadays, this method has become one of the popular methods in the agricultural system due to the more efficient use of resources and its role in the reduction in weeds interference and other pests (Chen *et al*., 2012; Lithourgidis *et al*., 2011). In Ethiopia, more than 95% of the country's agricultural output is generated by

subsistence farmers who, on average, own less than one hectare of cultivated land (USDA 2010). Agricultural productivity is, therefore, constrained by limited cultivation areas and high population growth.

The demand for medicinal and aromatic plants is increasing day by day at national as well as international markets. Therefore intercropping of aromatic and medicinal plants shall be advocated and adopted for obtaining additional remuneration for the farmers. Medicinal & aromatic plant like Rosemary (Rosmarinus officinalis L) is an aromatic perennial shrubby herb that belongs to the family Labiatae (Directorate plant production, 2009). The dried leaf material and essential oil of rosemary are obtained from leaves and flowering twigs. The leaves are used as a culinary herb and essential oil is extensively used in food, Flavor and fragrance industries (Beemnet et al., 2013). Essential oil is also used almost wholly in the perfumery industry for the production of soaps, detergents, household sprays and other products (Joy *et al*., 2001). It is a vegetative propagated through a cutting and it is initially slow growing. The wide uncovered interspaces between the rows of rosemary harbor a large number of weeds in the initial stage of crop growth resulting in suboptimal utilization of natural resource and inputs leading to yield losses and increased the cost of cultivation (Rajeswara Rao *et al*.1993). Crop diversification, following intercropping and agro forestry, has been reported to be a potential alternative for enhancing per capita (unit area and time) productivity in the context of shrinking land holding and increasing human and livestock population (Swaminathan, 2001).

Carrot (Daucus carota L.) is a widely grown root vegetable of the Apiaceae family. Carrots have been one of the most important means used to mitigate vitamin A deficiency. Carrot roots are a rich source of carotenoids, precursors of vitamin A. The carotenoids contained in the edible portion of carrots can range from 6000 to more than 54,000 µg per 100g (60–540 ppm) (Simon and Wolff, 1987). Smallholder's farmers have limited landholding in the south region and the area highly populated therefore there is a need to improve land use system and the way to improve their income generation methods through intercropping of companion crops like carrot and rosemary. Therefore the study was initiated with the objective of intercropping rosemary (*Rosmarinus officinalis* L) with Carrot as a supplement income generation and to know the optimum proportion of rosemary in carrot.

MATERIALS AND METHODS

The research was conducted at Wondo Genet Agricultural Research Center's fields, in Southern Ethiopia during 2016-2018 growing seasons. Wondo Genet is located at 7°19'N latitude and 38°38'E longitude with an altitude of 1760-1920 m.a.s.l. The site receives a mean annual rainfall of 1372 mm with minimum and maximum temperature of 11.5°C and 26.2°C, respectively. The experiment was conducted on rosemary intercropping with Carrot as a supplement income generation to know the compatible and optimum proportion of rosemary in Carrot. The treatments were six intercropping ratio of rosemary -: T1= Sole carrot (25cm inter x5cm intra-row pacing), T2= Sole rosemary (60cm inter x 60cm intra-row), T3= 100% carrot + 25% of Rosemary(120cm inter-row x 120cm intra-row),T4=100% carrot + 50% rosemary (90inter-row x 80cm intra-row), T5= 100% carrot + 75% Rosemary (60inter-row x 80cm intra-row),T6= 100% carrot + 100% Rosemary (60 inter-row x 60cm intra-row spacing). Carrot variety named Nantes used as main crop and Rosemary as companion crops.

The design was laid out in randomized complete block (RCBD) with three replications. Spacing between plots and replication were 1m and 1.5m respectively. The plot size was 8.64m^2 (3.6 width and 2.4m length). Rosemary seedling was raised on the nursery for three months before transplanting to the actual field. Rosemary seedling was transplanted according to plant geometry of intercropping ratio in row additive series and simultaneously Carrot seeds mixed with sand were directly sown inline row spacing of 25cm by hand and covered lightly with soil. Seedlings of carrot were thinned to a plant to plant distance of 5cm, soon after to established population density of the main crop. Recommended inorganic fertilizer 64 N kg ha^{-1} and 46 kg ha^{-1} P_2O_5 (TSP) for carrot was used. Rosemary harvesting was done at the nine-month interval after transplanting for two subsequent years.

Data to be collected

Plants from the center were harvested by excluding border rows to collect yield and yield contributing characters for rosemary on plant height, number of branch plant^{-1}, fresh leaf weight plant^{-1}, fresh stem weight plant^{-1}, dry above ground biomass plant^{-1}, for carrot on root core diameter (cm), root length (cm), root weight (gm) and root yield (kg pot^{-1}) were recorded during each harvesting. Essential oil content and essential oil yield of rosemary were determined by taking 300g of fresh leaves and stem composite samples harvested from three middle rows of a plot. Analysis of variance was used to test the significance of treatment effects using the computer program SAS 9.1.3. Least Significant Difference (LSD) test was used to compare treatment means.

Land Equivalent ratio was calculated as given below:

LER = (CY in /CYs) + RY in/RYs), Where,

CY in and RY in = was yields of Carrot in intercropping and yield of rosemary in intercrop respectively, and CYs and RYs = were carrot yields in sole and rosemary yield in sole respectively

The economic advantage of the intercropping system was calculated by

Prevailing local market prices of carrot and rosemary were taken for economic analysis and the prices of carrot and Rosemary were 6 and 36.4 ETB/Ethiopian Birr), respectively, during the experiment.

The monetary advantage index (MAI) = (Value of combined intercrops) x (LER-1)/LER
LER = Land equivalent ratio

The higher the MAI value the more profitable is the cropping system (Ghosh, 2004).

RESULTS AND DISCUSSION

Carrot components

Table 1 show that growth and yield of carrot for two years. The result revealed that root core diameters (cm2), root length (cm), and carrot yield (kgha^{-1}) were not influenced by the intercropping ratio of rosemary in 2017 cropping season. Even though the ratio of rosemary intercropping varied carrot yield was not influenced; it might be the reason due to low nutrient competition at the beginning of rosemary
Plant development and wide uncovered space found between the rosemary plants attributed to carrot yield.

Similar finding was reported by Mondal *et al* (2012) intercropping carrot with ground not affect growth and carrot yield. However, in 2018 cropping season carrot yield was significantly affected by the intercropping ratio of rosemary. Maximum carrot yield (21t ha^{-1}) was found from the sole cropping which was statistically in par with carrot yield (15.1t ha^{-1}) obtained from 25% of rosemary intercropping into 100% carrot and the lowest carrot yield (3.8t ha^{-1}) was obtained from the 100% of rosemary intercropping with 100% carrot.

This result showed us the perennial nature of rosemary affect carrot yield in the second year because when roots and canopy of rosemary fully developed competition occurred would affect carrot yield. When the intercropping ratio of rosemary increased to 50%, 75% & 100% carrot yield were significantly decreased. A similar result was reported by Nigussie *et al* (2017) Onion bulb yield reduction was observed by intercropping rosemary with onion, compared with pure stand onion. Also, this result is in agreement with findings by Kabura *et al*. (2008), and Trdan *et al*. (2006), who reported that intercropping leek with carrot reduced yields. Similar results were obtained by Salman (2017) carrot: onion: broad bean intercropping.

Rosemary Components

Plant height (cm), number branch per plant and dry leaf yield (kgha^{-1})

Table 2 & 3 Showed that growth and yield of rosemary for two years. In 2017 cropping season plant height of rosemary was not affected by intercropping ratio; however in 2018 cropping season plant height was significantly affected by the intercropping ratio of rosemary. Maximum plant height (cm) was obtained from the intercropped ratio of recommended 100% rosemary with 100% carrot which was statistically similar with plant height recorded from 75% rosemary with 100% carrot. The lowest plant height (95.3cm) and (90.1cm) recorded from the sole stand and 25% of rosemary respectively. This higher rosemary plant height recorded from high number of intercropping ratio may be explained by increased activity of stem growth hormone for plant sunlight competition. Numbers of branches per plant were not varied among the treatments in both years. In 2017 cropping season significantly higher dry leaf yield (3301.7kgha^{-1}) was obtained from the sole stand and followed by dry leaf yield(2467.9 kgha^{-1}) obtained from75% of rosemary intercropping. Similarly in 2018 cropping season maximum dry leaf yield (5371.3kgha^{-1}) obtained from sole stand followed by dry leaf yield (5513.1kgha^{-1}) obtained from 100% rosemary with 100% carrot (Table 2). This high amount of dry leaf yield per hectare at the sole stand 75% and 100% of rosemary intercropping in carrot could be due to the number of high rosemary accommodation per unit area.

The yield difference between the years also due to the perennial nature of rosemary after nine-month harvesting the second year data was collected from the ratoon plant that could develop more leaf yield. In both years the lowest dry leaf yield (900kgha^{-1}) and (1346.6kgha^{-1}) were recorded from the 25% of rosemary intercropping (Table 2).

Above ground biomass (kgha^{-1}), Oil yields (kgha^{-1}) and Oil content

Table 3 showed that above ground biomass and oil yield per hectare was significantly affected by the intercropping ratio of rosemary in 2017 and 2018 cropping seasons. Maximum above ground biomass (7002.9 kg ha^{-1}) and (10074 kg ha^{-1}) were obtained from

Table: 1 Effect of Carrot-Rosemary intercropping ratio on yield and yield components of carrot at WGARC in 2016/17 to 2017/18 cropping season.

Treatments	Root core diameter (cm^2)			Root length(cm)			Carrot yield (t ha^{-1})		
	2016	2017	Mean	2016	2017	mean	2016	2017	Mean
Sole Carrot	3.10	2.91	3.1	15.91	13.16	14.5	23.8	21.0a	22.4
100%C +25%R	3.12	2.89	3.1	16.4	13.7	15.1	25.4	15.1ab	20.3
100%C+50% R	3.06	2.63	2.8	11.96	11.4	11.7	21.0	10.3b	15.6
100% C+75% R	3.45	2.86	3.6	12.1	13.3	12.7	26.1	8.0bc	17.1
100%C+100%R	3.01	2.62	2.8	11.1	11.4	11.3	30.7	3.8c	17.3
LSD (0.05)	ns	ns		Ns	ns		ns	9.58	
CV%	30	9.6		25.5	15.4		14.7	23.5	

Key, R= for rosemary and C for carrot, similar letter within the same column are statistically same, CV= for the coefficient of variation LSD=List Significant Differences at 5%

Table: 2. Effect of Carrot-Rosemary intercropping ratio on yield and yield components of Rosemary at WGARC in 2016/17 to 2017/18 cropping season

Treatments	PH			NBPP			DLW kg ha^{-1}		
	2016	2017	Mean	2016	2017	mean	2016	2017	mean
Sole Rosemary	92.1	95.3bc	93.7	48.3	56.5	39.3	3301.7a	5371.3a	4336.5
100%C+25%R	98.8	90.1c	94.45	64.7	62.9	48.8	900.0c	1346.6c	1123.3
100%C+50% R	98.1	95.4bc	96.75	66.1	58.6	46.3	1517.8c	2100.1b	2175.3
100% C+75% R	91.2	105.8ab	98.5	57.9	60.31	35.7	2467.9b	1964.6b	2153.5
100%C+100%R	99.8	106.1a	102.9	37.1	50.5	33.7	2335.2b	5513.1a	3924.2
LSD (0.05)	ns	10.5		Ns	ns		647.63	563.13	
CV%	6.0	5.7		21.4	19.8		16.3	18.4	

Key, R= for rosemary and C for carrot, similar letter within the same column are statistically same, CV= for the coefficient of variation LSD=List Significant Differences at 5%

Table: 3. Effect of Carrot-Rosemary intercropping ratio on yield and yield components of Rosemary at WGARC in 2017 to 2018 cropping season

Treatments	Dry above ground biomass (kg $ha^{-1)}$			Oil Yield(kg $ha^{-1)}$			Oil Contents		
	2016	2017	mean	2016	2017	mean	2016	2017	Mean
Sole Rosemary	7002.9a	10074a	8538.5	33.7a	60.6a	47.2	1.0	1.13b	1.07
100%Carrot+25%R	1760.9d	2640c	2200.5	10.0c	16.7b	13.4	0.91	1.14b	1.03
100%C+50% R	3040.0c	3213c	4093.3	12.4c	25.9b	23.6	0.83	1.22ab	1.02
100% C+75% R	4973.6b	5013.9b	4026.5	22.5b	27.6b	24.2	0.82	1.40a	1.11
100%C+100%R	4757.4b	10163a	7460.2	23.1b	63.1a	43.1	1.1	1.24ab	1.17
LSD (0.05)	1222.3	1764.6		8.6	13.95		0.49	0.25	
CV%	15.1	19.9		22.6	19.1		26.6	10.9	

Key, R= for rosemary and C for carrot, similar letter within the same column are statistically same, CV= for the coefficient of variation LSD=List Significant Differences at 5%

Table: 4. Land equivalent ratio and monetary advantage of carrot and rosemary intercropping ratio at WARC in 2016/17 up to 2017/18 cropping season

Treatments	The land equivalent ratio of total			Monetary Advantage Indices'		
	2016	2017	Mean	2016	2017	Mean
100%C+25%R	1.33b	1.23b	1.28	171378a	98768a	135073
100%C+50% R	1.38ab	1.31ab	1.35	145556a	32804b	77409
100% C+75% R	1.83ab	1.44ab	1.63	67620b	9263b	50212
100%C+100%R	1.94a	1.71a	1.83	63324b	1848b	32586
LSD (0.05)	0.57	0.44		69855	64939	55410
CV%	17.45	15.5		31.2	28.7	

Key, R= for rosemary and C for carrot, letter within the same column, CV= for the coefficient of variation LSD=List Significant Differences at 5%

the sole stand and 100% of rosemary intercropping with 100% carrot in 2017 and 2018 cropping season respectively. The lowest aboveground biomass also recorded from the intercropping ratio of 25% rosemary. With a similar trend to above, ground biomass significantly higher oil yield (33.7kgha^{-1}) and (60.6kgha^{-1}) were recorded from the sole stand and 100% rosemary intercropping with 100% carrot. The lowest oil yield (10kg ha^{-1}) and (16.7kg ha^{-1}) were recorded from the 25% of rosemary intercropping in a first and second year respectively (Table 3).

This reduced oil yield of rosemary at 25% might possibly be due to the reduction of dry leaf yields in the intercropped treatments. This finding was in line with previous similar findings in onion intercropped with rosemary by Nigussie *et al* (2017). The related result was also reported by Lulie *et al*., (2014) in intercropped maize with spearmint. Oil content in 2017 cropping season recorded was not affected, however, in 2018 cropping season significantly higher oil content (1.4%) was found in 75% of rosemary intercropping which were statistically similar with oil content recorded from both (50% and 100% of rosemary intercropping ratio).

This finding was in line with previous similar findings in onion intercropped with rosemary by Nigussie *et al* (2017) and on Rose-scented geranium intercropped with vegetables (Rajesh et al., 2011). (Figure 1)

Land Equivalent Ratio

The total land equivalent ratio was significantly affected by the intercropping ratio of rosemary in carrot in both years. All intercropping ratio system was given greater than one indicating that, the advantageous of intercropping than the mono cropping system. In 2017 cropping season higher total land equivalent ratio of total (1.94) recorded from 100% rosemary intercropping in 100% carrot followed by LERt (1.83) from 75% of rosemary intercropping in 100% carrot. The lowest LERt (1.33) recorded at the intercropping ratio of 25% rosemary in 100% carrot. Similarly in 2018 cropping season maximum LERt (1.71) at 100% rosemary intercropping in 100% carrot and the lowest LERt (1.23) obtained from the intercropping ratio of 25% rosemary. The highest pooled mean LERt (1.83) was obtained from the intercropping proportion of 100% rosemary in 100% carrot which might be attributed to more efficient total resource exploitation and greater than the overall intercropping ratio. This indicated that an additional 0.83 ha (83%) more area would have been needed to get equal yield to plant carrot and rosemary in pure stands (Table 4). This finding was in line with previous similar findings in onion intercropped with rosemary by Nigussie *et al* (2017). Other studies also reported advantages of intercropping systems where, LER of greater than 1(Temesgen and Wondimu , 2012; Kidane *et al*., 2017).

Monetary Advantage

MAI also used to evaluate the economic advantages of the intercropping system. Monetary advantage index was significantly ($p<0.05$) influenced by the intercropping ratio of rosemary in carrot in both years. In 2017 cropping season maximum monetary advantage index (171,378 birr ha-1) was obtained from the intercropping ratio of 25% in 100% carrot which was statistically similar with the monetary advantage index (145,556 birr ha^{-1}) obtained from 50% rosemary intercropping.

The lowest MAI (63324birr ha^{-1}) was recorded from the 100% rosemary intercropping in 100% carrot. In 2018

Picture: Pictorial presentation of carrot-rosemary intercropping as a supplementary income generation

cropping season also in similarly trend maximum MAI (98768 birr ha^{-1}) was recorded from 25% of rosemary intercropping and the lowest MAI (1848 birr ha^{-1}) obtained from 100% rosemary intercropping (Table 4). This maximum monetary advantage index might be due to the value of the land equivalent ratio. These finding in accordance with the finding of Lulie et al., (2014) in intercropped maize with spearmint; Nigussie *et al* (2017) in onion intercropping with rosemary.

CONCLUSION

The experimental conducted for two-year results have demonstrated that intercropping rosemary with carrot showed the advantage of the intercropping system. From the result, we found intercropping 25% and 50% of rosemary with 100% carrot gave significantly higher in terms of monetary advantage index. Therefore, for additional income generation for small scale farmers and intensive agriculture system; we recommend an intercropping ratio of rosemary from 25% up to 50% of recommended rosemary population density with carrot would help for additional income generation than mono-cropping either of the crop.

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