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Ethiopian Rue (*Ruta chalapensis L.*) Genotypes Morphological and Biological Performance at Different Locations of Southern Ethiopia

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Abstract

Rue is an aromatic is evergreen plant used for multipurpose that used for traditional medicine and in Ethiopia mainly used flavoring coffee addition to its medicinal benefit. There is limitation of knowledge, experience, modern scientific evidences and information on Ethiopian *R. chalenpesnsis* genotypes because the experiment was undergone the aim to minimize the aforementioned gaps. The experiment was held for one year in 2019 up to 2020 G.C. at three different locations using 10 (ten) selected promising superior genotypes from selected during characterization of accessions. Selected genotypes were tested using Randomized Complete Block Design following the procedures of Gomez and Gomez in three replications. Rue genotypes were planted in six rows of 3-meter length on the commencement of main rainy season using 60 cm between plant and row spacing. Data was collected from different traits such as; plant height, number of branches/plants, fresh leaf weight/branch, fresh leaf weight/plant, leaf to stem ratio, leaf yield/ha, percent essential oil content and essential oil yield/ha. All tested traits very significantly affected by locations and genotypes during this experiment. The phenology of the genotypes is highly affected by location different; rue genotypes give more fruits early at high land and more leaves at low lands. Maximum leaf yield and leaf essential oil yield/ha was obtained at Arba Minch and maximum fruit essential oil yield/ha at Wondo genet from genotypes 1and 5 respectively. Based on this experiment result high altitude agroecology is more suitable for production and low altitude is for leaf production.

Keywords: *Ruta chalepensis* • Essential oil content • Essential oil yield • Leaf yield • Fruit yield

Introduction

Rue *(Ruta chalepensis)* is an aromatic evergreen herb or small shrub belongs to *Rutaceae* family [1,2]. *Rutaceae* family contains about 160 genera and more than 1600 species. The genus name "Ruta" comes from the Greek word "reuo ", to set free, showing its reputation as a free from disease [3]. All these species are with bluish-green leaves emit a powerful odour and have a bitter taste [4]. From this entire species, *Ruta graveolens* and *Ruta chalepensis* are the mainly used species in traditional medicine with various benefit [5]. *Ruta chalepensis L*. is a native to the Mediterranean region and later widely diffused in many parts of the world, in temperate and tropical countries worldwide [6]. *R. chalepensis* is the mainly used in rue species traditional medicine by many countries addition to *Ruta garveolens* to treat a variety of diseases [7]. It has been introduced in several of North, Central and South America, China, India, Middle East and South Africa for different cultural and medicinal value due to its medicinal and different cultural value [8]. In Chile, it is traditionally cultivated for its pharmacological uses; infusions of its fresh leaves are widely used as treatment for gastric disorders, headache and rheumatism. In Ethiopia *Ruta chalepensis* known as 'Tena adam' in Amharic, 'Cirakota' in Afan oromo, 'Chena-adam' in Tigrigna and called in different names by different Ethiopian ethnics [9]. All Ethiopian population are highly familiar with rue and grown in their farm guard as spices and also used as traditional healer for children and matured person. When you see Ethiopian coffee ceremony the plant rue or 'Tena adam' comes to your mind because coffee and Rue are highly attached in use. The leaves are boiled with tea or coffee and drunk alternatively, the leaves are crushed and pounded and mixed with cold water and drunk as a treatment to stomachache. Crushed seeds of *R. chalepensis* and seeds of *L. sativum* are added to water and sprayed in homes or home compounds or crop fields to repel evil (bad) spirits. Crushed seeds and/or leaves of *R. chalepensis* and bulb of *A. sativum* are smeared or rubbed on bleeding head or forehead damaged during physical damage when someone falls over or beaten by someone, to prevent infection [3]. Despite, rue is popularly used by Ethiopian population, there are limitation of knowledge, experience, improved variety and scientific information for production and further variety improvement works. This experiment was aimed to identify, quantify yield and yield components of Ethiopian rue genotypes for the selection of superior genotypes for national variety trials.

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Research Methodology

Experimental duration and site

Experiment was undertaken for one (2019-2020 G.C.) year at three locations such as Jajura, Wondo Genet and Arba Minch using 10 selected genotypes collected from different locations throughout the country from farmers' garden.

Experimental procedure

Promising genotypes following preliminary screening and characterization activities were tested using Randomized Complete Block Design (RCBD) following the procedures of Gomez and Gomez [9] in three replications. Rue genotypes were planted in six rows of 3-meter length on the commencement of main rainy season using 60 cm between plant and row spacing. All agronomical management such as; hoeing, weeding and pinching of flowers flowered at very early stage to have enough biomass for more leaf and fruit yields. Supplement irrigation was given for the plant at all location when rain was not enough and totally absented at off season. No fertilizer or chemical was applied during experimentation. Respective spacing of 1.5 m and 1 m will be maintained between replications and plots. During the activity, data on plant height, number of branches/plants, fresh leaf weight/branch, fresh leaf weight/plant, leaf to stem ratio, leaf yield/ha, percent essential oil content and essential oil yield/ha were recorded critically. Data on quantitative traits was subjected for statistical analysis using SAS computer software following

the procedures of the general linear ANOVA. The promising genotypes were promoted to national variety testing.

Results and Discussion

Morphological observation and phenology

Genotypes tested are highly variable morphologically and phenologically at tested location. All genotypes flowered at Jajura and Wondo Genet but only two genotypes flowered and bear fruit lately. The performance of all genotypes was significantly different and highly affected by location and different genotype (Table 1). Production of leaf more favorable at low altitude and fruit is more productive at high altitude and mid-latitude. Giant genotypes are high yielder and dwarf or stunted growth rue genotypes less productive but early flower than the giant one. Generally this experiment result revealed that *R. chalepensis* nearly flower uniformly at mid and high altitude but lately flower or not totally flower at low land altitude maturity date for fruit yield.

Plant height

Plant highly significantly affected by genotypes and grown location (Table 1) Maximum mean plant height was obtained at Arba Minch from genotype 1 (105.29 cm) long and minimum at Jajura from genotype 6 (63.0 cm) long. Plant height is highly variable in genotype and highly affected by location (Table 1).

Rue (*Ruta chalepensis L.*) fruit yield

Ruta chalepensis identified by its fingered fruits from R,graveolens and each fruit have four finger and five fingered fruit at center of the plant fruits as Asgarpanah and Khoshkam, [10] discussed in their article. Rue genotypes fruit are variable in size, arrangement and yield at different location (Figure 1). Rue size small, mid-size and larger and some genotype was not bear fruit at all. Fruit bearing genotypes produce fruit yield range from 597-3213 kg in average at tested locations Wondo Genet and Jajura but only two genotypes only bear fruit at Arba Minch Site. This result revealed that mid-altitude like Wondo Genet and Jajura is suitable for rue fruit yield and low altitude like Arba Minch is not suitable for production rue fruit [11].

Leaf weight /plant and leaf yield /hectare

Leaf weight/plant and leaf yield/hectare is highly significantly affected by genotypes and locations (Table 2). Maximum leaf weight/plant was obtained from genotype 5 (849.8 g) at Arba Minch and low weight/plant obtained from genotype 6 at Jajura (28.73 g). This experiment revealed that as altitude increase leaf yield decrease. Lowland area is more suitable than highland areas for the leaf production rue (*Ruta chalepensis* L.). Based on this result, we can cultivate rue genotypes on mid-high-altitude locations but agroecology of Arba Minch and similar agroecology is very suitable for rue leaf yield and yield component.

Leaf essential oil content

Leaf is one the main economical part used as spices and for essential oil extraction used for numerous benefits. Ethiopian rue genotypes essential oil content of genotype was significantly different and showed significant difference at tested locations (Table 2). Maximum fresh leaf essential was obtained from genotype 9 (0.261%) at Wondo Genet (Table 3).

Leaf essential oil yield /hectare

Essential oil yield is highly significantly affected by genotypes and location addition to these, essential oil components leaf essential oil content and leaf yield directly affected essential oil yield. Maximum essential oil obtained from genotype 2 (18.43 kg) at Arba Minch (Table 4).

Table 1. Experimental area description.

Location	Latitude	Longitude	Altitude (m)	Soil type	Temperature		Annual mean rain fall
					Minimum	Maximum	
Wondo Genet	7° 192' N	38° 382' E	1780	Sandy Loam	14°C	26°C	1078.7mm
Arba	6° 0' 0" N	37° 35' 0" E	1200	Clay Loam	20°C	27°C	1100 mm
Jajura Minch	Unavailable	Unavailable	2200	Clay Loam	18°C	25°C	2370 mm

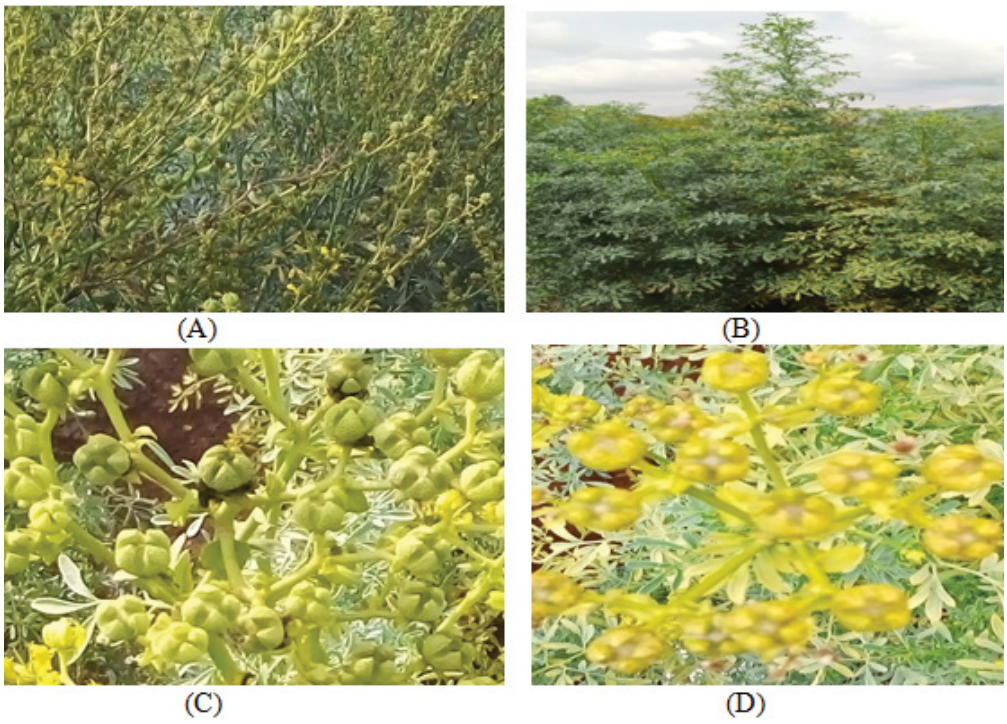

Figure 1. Ethiopian Ruta chalepensis genotypes fruit variability, (A) small size fruit, (B) genotype with no fruits, (C) genotype with large fruit size (D) central Ruta chalepensis with five fingers.

Table 2. ANOVA table for traits evaluated three locations for variability of Ethiopian rue genotypes.

SV	DF	PH	IL	BN	FLWP	FLYHA	FLEOC	FLEOYHA
TRT	9	1067.30	1.74	517.35	18550.1	20258279	0.018	75.91
REP	2	1.72	0.044	253.61	28511.	19729535	0.0001	36.16
LOC	2	14411.93	3.56	13172.58	2630631.3	1723039911	0.23	1789.71
TRT × LOC	18	203.94	0.39	517.24	27349.73	16256266	0.02	70.012
ERROR	58	42.93	0.11	132.57	14273.1	11328961	0.0004	34.07
R^2 %		94.42	81.99	84.15	87.84	85.77	97.28	73.90
CV %		8.11	18.79	30.71	44.82	41.69	13.20	61.00
Mean		80.81	1.79	37.49	266.56	8073.51	0.16	9.57

PH: Plant Height, IL: Internode Length, BN: Branch Numbers, FLWP: Fresh Leaf Weight Per Plant, FLYH: Fresh Leaf Yield Per Hectare, FLOC: Fresh Leaf Essential Oil Content, FLEOYH: Fresh Leaf Essential Oil Yield Per Hectare.

Table 3. Mean comparison of Ethiopian genotypes performance at Wondo Genet Arbaminc and Jajura.

Treatment	Evaluated traits						
	PH	IL	BN	FLWP	FLYHA	FLEOC	FLEOYHA
1	100.74	2.60	42.70	240.61	6111.118	0.209	7.99
2	84.48	1.63	28.89	292.71	9008.76	0.212	13.02
3	63.22	1.56	35.44	282.75	8828.36	0.158	9.82
4	89.55	1.63	25.89	237.24	7559.65	0.124	8.114
5	86.44	2.20	35.67	340.42	10085	0.136	12.99
6	69.07	1.86	51.41	178.73	5109.65	0.12	4.48
7	83.33	1.78	45.67	296.38	8837.03	0.158	12.07
8	73.70	1.23	38.00	231.31	7628.78	0.132	8.843
9	74.52	1.25	33.85	271.60	8582.41	0.244	11.88
10	83.00	2.24	37.41	293.60	8984.632	0.122	6.48

PH: Plant Height, IL: Internode Length, BN: Branch Numbers, FLWP: Fresh Leaf Weight Per Plant, FLYH: Fresh Leaf Yield Per Hectare, FLOC: Fresh Leaf Essential Oil Content, FLEOYH: Fresh Leaf Essential Oil Yield Per Hectare.

Table 4. Mean comparison of Ethiopian genotypes performance at Wondo Genet Arbaminc and Jajura.

Traits	Location name		
	Wondo Genet	Jajura	Arba minch
PH (cm)	74.12	63.0	105.29
IL	1.94	2.04	1.40
BN	17.92	34.55	59.60
FLWP (g)	59.09	134.92	605.68
FLYHA (kg)	3648.85	3747.38	16824
FLEOC	0.261	0.114	0.106
FLEOYHA (kg)	5.986	4.287	18.434

PH: Plant Height, IL: Internode Length, BN: Branch Numbers, FLWP: Fresh Leaf Weight Per Plant, FLYH: Fresh Leaf Yield Per Hectare, FLOC: Fresh Leaf Essential Oil Content, FLEOYH: Fresh Leaf Essential Oil Yield Per Hectare.

Table 5. ANOVA table of Ethiopian *Ruta chalepensis* tested at Wondo Genet and Jajura in 2019.

SV	DF	PH	IL	BN	IL	FLWP	FLYH	FFWP	FFYH	LEOC	LEOYH	FEOC	FEOYH
TRT	9	513.4	1.59	346.13	108.2	3079.76	1913022	69117.6	6527929.7	0.03	21.04	0.025	24.24
REP	2	5.95	0.02	600	20.11	3223.19	2919370	95861.78	5411421.4	0	4.56	0	14.32
LOC	2	1852.04	0.145	4351.68	14.35	86220.23	145606	1040685.5	1644335.3	0.33	43.3	0.096	9.24
TRT × LOC	9	44.06	0.37	210.4	34.81	7148.23	2229935	36982.45	2987463.2	0.03	11.17	0.07	22.76*
ERROR	38	31.07	0.137	64.89	7.62	1720.7062	1667351.9	21345.097	1623792.3	0	1.88	0.003	3.91
R^2 %		85.35	0.77	81.07	82.24	73.86	40.5803	72.9487	61.39	99.92	82.76	99.03	75.61
CV %		8.13	18.63	30.47	10.47	42.77	34.9167	76.5762	69.43	2.2	26.67	5.26	60.52
Mean		68.56	1.99	26.44	26.37	97	3698.12	190.79	1835.47	0.19	5.14	0.19	3.27

PH: Plant Height, IL: Internode Length, BN: Branch Numbers, FLWP: Fresh Leaf Weight Per Plant, FLYH: Fresh Leaf Yield Per Hectare, FLOC: Fresh Leaf Essential Oil Content, FLEOYH: Fresh Leaf Essential Oil Yield Per Hectare.

Fruit Essential oil content and Fruit essential oil/hectare

Maximum essential oil content was obtained from genotype 9 (0.33%) and maximum essential oil yield was obtained from genotype 1 (7.25 kg) at Wondo Genet (Table 5). This result came from genotypes nature for essential content and leaf yield.

Internodes length

Maximum internode obtained at Wondo Genet 3 cm (genotype 1) and low minimum internode at Wondo Genet 0.98 cm (genotype 9) (Tables 6 and 7).

Table 6. Mean comparison of genotypes tested at Jajura and Wondo Genet in 2012 E.C.

TRT	PH	IL	BN	INMS	FLWP	FLYHA	LSR	LEOC	LEOYH	NFP	FFWP	FFYH	FEOC	FEOYH
1	79.11	2.59	20.67	24.72	147.47	3237.82	1.33	0.28	8.365	128.72	285.29	2400.58	0.25	7.25
2	76.61	1.77	16.67	31.53	113.44	4467.93	2.04	0.255	8.045	19.22	118.91	1170.25	0.24	2.66
3	56.34	1.8	24.22	27.06	107.36	4443.47	2.75	0.16	4.373	18.84	133.98	841.22	0.165	1.367
4	78.33	1.76	15.99	31.17	74.12	3513.55	1.63	0.13	3.357	13.89	145.48	1446	0.175	2.34
5	72.22	2.62	35.45	21.45	85.74	3324.82	0.91	0.145	4262	83.89	250.13	3195.54	0.18	5.45
6	53.66	2.19	31.28	20.16	91.14	2749.2	0.78	0.147	3.585	100.94	297.66	3213.78	0.135	4.46
7	75.61	2.03	35.11	26.17	106.17	3855.7	1.38	0.152	6.023	53.99	225.01	2610.81	0.15	4.46
8	62.45	1.26	26.06	28.42	89.77	4298.87	2.32	0.13	3.525	5.61	51.86	597.01	0.125	0.753
9	63.44	1.27	23.22	31.11	70.17	3506.17	2.2	0.303	6.008	5.78	43.72	519.94	0.33	1.5
10	67.89	2.61	35.72	21.89	84.59	3583.52	1	0.152	3.85	77.45	355.88	2359.6	0.14	3.27

PH: Plant Height, IL: Internode Length, BN: Branch Numbers, FLWP: Fresh Leaf Weight Per Plant, FLYH: Fresh Leaf Yield Per Hectare, FLOC: Fresh Leaf Essential Oil Content, FLEOYH: Fresh Leaf Essential Oil Yield Per Hectare.

Table 7. Genotypes and locations interaction mean comparison of Ethiopian rue accessions tested at different three locations in 2012 E.C.

TRT	LOC	N	PH		IL		BN		FLWP		FLYHA		FLEOC		FLEOYHA	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	S Dev	Mean	Std Dev	Mean	Std Dev
1	WG	3	86.78	7.62	3	0.24	14.9	1.5	156.2	45.2	2623.06	701.39	0.43	0	11.7	1.49
1	JAJURa	3	71.44	4.83	2.18	0.46	26.4	4.07	138.7	27.67	3852.78	768.7	0.13	0	5.01	1
1	AM	3	144	6.11	2.61	0.39	86.8	13.43	426.9	145.82	11857.7	4050.39	0.07	0.03	7.23	0.65
2	WG	3	81.67	6.23	1.49	0.19	14.9	1.35	33.49	1.09	3563.64	640.46	0.37	0	8.57	0.64
2	JAJURa	3	71.56	4.5	2.05	0.5	18.4	4.54	193.4	59.02	5372.22	1639.23	0.14	0	7.52	2.29
2	AM	3	100.22	6.84	1.33	0.3	53.3	29.49	651.3	155.7	18090.4	4325.08	0.13	0.02	23	6.36
3	WG	3	61.56	7.88	1.93	0.55	19.6	3.95	28.62	20.93	3717.5	1403.8	0.23	0	4.09	1.07
3	JAJURa	3	51.11	7.85	1.67	0.6	28.9	10.57	186.1	114.54	5169.45	3181.81	0.09	0	4.65	2.86
3	AM	3	77	5.51	1.06	0.01	57.9	16.52	633.5	264.32	17598.2	7342.22	0.11	0.05	20.7	16.66
4	WG	3	80.22	3.27	1.57	0.32	13.9	2.99	28.73	4.93	3707.34	967.37	0.13	0	2.4	0.11
4	JAJURa	3	76.44	4.83	1.94	0.26	18.1	4.3	119.5	34.68	3319.75	963.39	0.13	0	4.31	1.25
4	AM	3	112	7.05	1.33	0.06	45.7	17.04	563.5	184.51	15651.9	5125.47	0.11	0.04	17.6	9.03
5	WG	3	80.33	4.04	2.64	0.26	19.8	2.46	75.03	16.85	3970	2096.84	0.22	0	6.65	1.08
5	JAJURa	3	64.11	6.77	2.6	0.05	51.1	17.34	96.46	16.03	2679.63	445.28	0.07	0	1.88	0.31
5	AM	3	114.89	6.71	1.35	0.06	36.1	6.95	849.8	381.82	23604.3	10606.1	0.12	0.04	30.5	20.61
6	WG	3	62	3	1.94	0.36	19.8	7.56	104.9	41.2	3348.09	971.06	0.17	0	4.5	0.41
6	JAJURa	3	45.33	1.73	2.44	0.65	42.8	10.36	77.41	9.79	2150.31	271.8	0.12	0.01	2.67	0.56
6	AM	3	99.89	10.46	1.19	0.26	91.7	10.39	353.9	110.4	9830.56	3066.71	0.07	0.05	6.26	3.87
7	WG	3	83	9.33	1.84	0.38	19.78	7.19	57.68	32.7	3415.4	983.83	0.22	0	6.59	2.31
7	JAJURA	3	68.22	3.56	2.22	0.27	50.45	16.85	154.66	77.89	4295.99	2163.62	0.12	0.01	5.41	3.02
7	AM	3	98.78	13.96	1.27	0.16	66.78	5.68	676.79	158.11	18799.69	4391.95	0.13	0.01	24.2	4.07
8	WG	3	70.22	2.5	1.11	0.08	21.11	5.06	28.6	33.67	4405.15	797.86	0.17	0	3.27	0.11
8	JAJURA	3	54.67	3.85	1.41	0.26	31	1.76	150.93	53.34	4192.59	1481.63	0.09	0	3.78	1.33
8	AM	3	96.22	5.68	1.17	0.29	61.89	17.71	514.39	128.36	14288.58	3565.49	0.14	0.01	19.48	4.75
9	WG	3	64.89	2.22	0.98	0.06	17.33	0.67	9.33	2.48	3373.15	901.1	0.5	0	8.13	0.59
9	JAJURA	3	62	8.09	1.55	0.41	29.11	3.65	131.01	11.83	3639.2	328.46	0.11	0.01	3.88	0.45
9	AM	3	96.67	6.03	1.21	0.47	55.11	5.35	674.46	61.44	18734.88	1706.62	0.13	0.06	23.63	10.05
10	WG	3	70.55	5.18	2.88	0.34	18.22	3.86	68.31	12.49	4365.19	779.3	0.17	0	3.95	0.4
10	JAJURA	3	65.22	2.46	2.34	0.2	53.22	27.8	100.87	33	2801.85	916.78	0.13	0.01	3.75	1.29
10	AM	3	113.22	8.27	1.49	0.22	40.78	11	712.32	232.12	19786.82	6447.59	0.06	0.02	11.75	2.11

Conclusion and Recommendations

Ethiopian rue genotypes highly influenced by location and genotypes and some genotype prefers high land for fruit bearing and all genotypes require low altitude for maximum leaf yield. Tis experiment revealed that rue is highly variable across location and there are different genotypes in Ethiopian. Based on morphological character 6 different genotypes selected and promoted to national variety trial for further performance evaluation. Finally, we recommend that there is some limitation in this experiment such as traits for more identification of fruit and phenology determination parameters was not included well as well as the experimentation site was limited to three location which cannot represents all Ethiopian agro ecology. In the next experiment aforementioned issues should be included for more important information of Ethiopian Rue genotypes.

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