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Effect of planting density on yield and yield components of lettuce (*Lactuca sativa* L.) at two agro-ecologies of Ethiopia

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Use of optimum plant spacing (planting density) is one of the important agronomic practices to maximize the productivity of lettuce. A field experiment was conducted to assess the responses of two lettuce varieties to different plant spacing at Debrezeit and Holeta Agricultural Research Centers representing two different agro-ecologies in Ethiopia. Nine treatment combinations of three levels of inter-row and three levels of intra-row spacing were studied on two types of lettuce varieties. The treatments were arranged in a randomized complete block design (RCBD) with three replications in a factorial experiment. The results revealed that marketable and total fresh leaf yield, and fresh leaf weight per plant were significantly affected by the main effect of plant spacing and variety as well as its interaction ($p<0.05$). Increasing planting density increased the total fresh leaf yield per unit area in both varieties, however reduced the fresh leaf weight per plant. The highest fresh leaf yield was obtained using 40 cm x 20 cm (125000 plants ha^{-1}) planting density from variety Great Lakes, while variety Rsk-3 recorded its highest fresh leaf yield at the highest planting density of 30 cm x 20 cm (166667 plants ha^{-1}). Great Lakes was superior over Rsk-3 in most yield parameters studied though Rsk-3 was better in leaf dry weight percent. Besides, both varieties responded differently in both sites while Great Lakes performed better at Debrezeit than at Holeta and Rsk-3 did well at Holeta than at Debrezeit. Hence, 40 cm x 20 cm and 30 cm x 20 cm could be used as the optimum plant spacing to grow Great Lakes and Rsk-3 respectively in the respective agro-ecologies.

Key words: Agronomic practices, planting density, inter-and intra-row spacing, competition.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the most popular vegetable crops which occupy the largest production area among salad crops in the world. It is produced commercially in many countries and also widely grown as a vegetable in home gardens (Kristkova et al., 2008). Lettuce is an important dietary vegetable, which is primarily consumed fresh in salads. Consumption of lettuce has some health benefits attributed to the presence of vitamin C, phenolic compounds, and fiber content (Vanisree et al., 2010). It is also rich in vitamin A

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and minerals like calcium and iron and also contains protein, and carbohydrate (MRC, 1954). Lettuce can grow in a variety of soil types and climatic conditions, which usually likes temperature between 23°C during the day and 7°C at night and grows within an altitude of 1800 to 2100 m.a.s.l. It is best grown in silt loams and sandy soils as these soil types provide better drainage and warm up more readily during the day, which is especially important during cooler periods of the growing season (Kristkova et al., 2008).

Globally, average production share of lettuce by region for the last 25 years (1994-2018) shows Asia (60.6%) took the lead followed by Americas (22.2%), Europe (14.8%), Africa (1.6%), and Oceana (0.8%). World production/yield quantities of the world of lettuce, has grown significantly during this period,; while in 2018 alone, about 27.3 million metric tons of lettuce was harvested from 1.27 million hectare of land (FAO, 2020).

Lettuce is among the widely grown vegetable crops in Ethiopia. In the Meher (or rainy) season of 2018, it was grown on 244.92 ha of land and produced 2,163.35 quintals involving 41,963 households (CSA, 2018). In Ethiopia, however data are not readily available for lettuce off-season production, although it is usually grown using irrigation in the dry season and, hence the quantity of production as well as the area coverage could certainly be higher than what was reported above. The average productivity of lettuce in Ethiopia is however very low compared to that of the world's average (CSA, 2018).

Plant spacing for lettuce cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield. Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development while on the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield.

Yield may be increased for any crop up to 25% by using optimum spacing in leafy vegetables such as lettuce (Bansal et al., 1995). There are different lettuce cultivars currently under production with different morphological characteristics such as head size, compactness, leaf color, and growth habits requiring different plant spacing. In Ethiopia, lettuce is usually grown by small holders where they cultivate few commercial and locally available varieties. However, due to lack of research recommended agronomic practices such as optimum planting density, growers use blanket recommendations which usually influence the crop performances and consequently reduce the productivity and quality attributes of the produce. Hence the present study was undertaken to find out the suitable plant spacing/or planting density for ensuring the higher yield and quality of two lettuce varieties in two agro-ecologies in Ethiopia.

MATERIALS AND METHODS

Description of study area

The present study was conducted at Debre Zeit and Holeta Agricultural Research Centers representing two different agro-ecologies in the Central and West Showa of the Oromia Regional State respectively in Ethiopia. The agro-ecological characteristics of the two experiment sites are described in Table 1.

Experimental plant materials

The study was conducted on two lettuce varieties (Great Lakes and Rsk-3). The varieties were selected for this study based on their domination in the production system, particularly Great Lakes and their differences in morphological traits, that is, head size, compactness and nature of growth habits. Great Lakes is a very popular head lettuce commercially available in the markets and widely grown by farmers. Its crisp heads have the perfect crunch that makes it perfect for garnishing sandwiches (Compositdb, 2006) (Figure 1A). Rsk-3 (Red lettuce) was introduced from Korea and was registered recently (2019) as variety in Ethiopia. It is red lettuce and open head growing type with high mineral content, rich in vitamin A, and suitable for continuous piece meal harvests (Zebenay et al., 2019) (Figure 1B).

Experimental design and treatment randomization

Nine combined spacing treatments of three levels of inter (30, 40 and 50 cm) and three levels of intra row spacing (20, 30 and 40 cm) were studied on the aforementioned two lettuce varieties. The treatments were laid out in a randomized complete block design (RCBD) in factorial arrangement in three replications.

Field management

Seedlings were raised on seed beds sown at a seed rate of 0.2 kg ha^{-1} and transplanted to the experimental plots (2 m x 1.8 m) at 3-4 weeks after sowing. At transplanting, seedlings were spaced on each experimental plot based on the spacing treatments to attain different planting densities (50000, 62500, 66667, 83333, 83333, 100000, 111111, 125000 and 166000 plants ha^{-1}). The plots were uniformly irrigated every 2-3 days after transplanting and soil moisture was kept at field capacity to avoid transplanting shock and irrigation continued at weekly interval until harvest. All experimental plots were fertilized with 100 kg of DAP ha^{-1} at transplanting and 180 kg ha^{-1} of Urea in splits, half applied at transplanting and the rest half three weeks after transplanting. Other agronomic practices including weeding, cultivation, pesticide application, etc were applied uniformly to all the experimental plots as per required.

Data collection and analysis

Fresh leaf weight per plant (g plant^{-1}), marketable fresh leaf yield per hectare (t ha^{-1}), unmarketable fresh leaf yield (t ha^{-1}), total fresh leaf yield (t ha^{-1}) and leaf dry weight percent (%), were the parameters for which data were collected for the study. Fresh leaf weight per plant and dry weight percent were measured from five sample plants taken per plot at full maturity. Leaf dry weight was measured by drying fresh leaf sample from each treatment in the oven at 65-70°C for about 48 h until a constant weight was attained. Data were subjected to analysis of variance (ANOVA) using R statistical software (http://www.R-project.org/, accessed online on June 5, 2020) and means were separated using least significant difference (LSD) test at 5% probability level.

Table 1. Agro-ecological data of Debre Zeit and Holeta Agricultural Research Centers.

Sites	Location (latitude and longitude)	Agro-ecological zones	Altitude (m.a.s.l)	Temperature (min/max) (°C)	Annual average rainfall (mm)	Soil types
Debre Zeit	08° 44' N and 38° 58' E	Tepid to cool sub-moist highlands	1900	8.9/28.3	851	Alfisols/Mollisols and Vertisols
Holeta	9º 00' N and 38º 30' E	Tepid to cool moist mountains and plateau	2400	6/22	1144	Nitosols and Vertisols

Source: MoA (1998): Agro-ecological Zones of Ethiopia (eiar.gov.et)

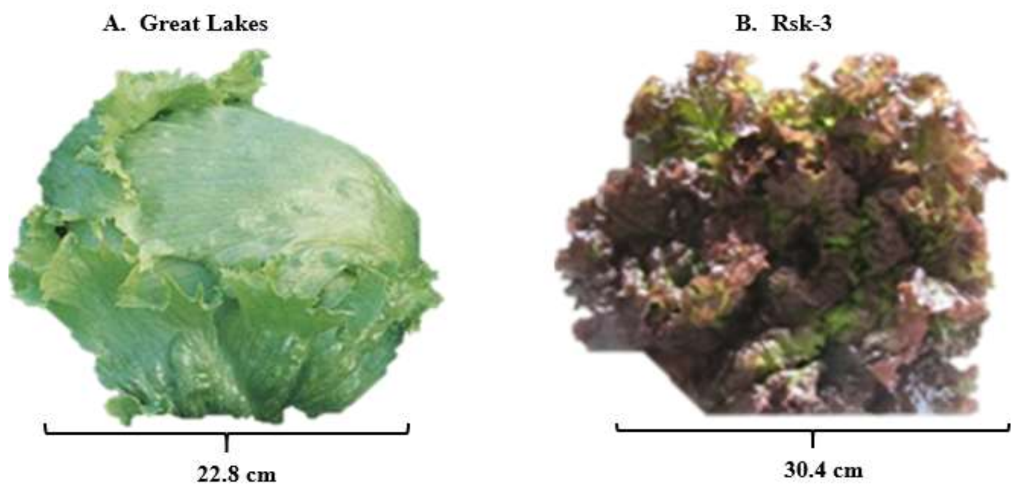

Figure 1. Photos showing the two lettuce varieties (A. Great Lakes and B. Rsk-3).

Table 2. Analysis of variance for leaf yield and dry weight percent of two lettuce varieties as affected by spacing and location.

Source of variation	Degrees of freedom	MFLY	UFLY	TFLY	FLWPP	LDW (%)
Rep	2	ns	ns	ns	ns	ns
Variety(V)	1	***	**	***	***	***
Spacing(S)	8	**	ns	***	***	ns
Location(L)	1	***	ns	***	ns	ns
VxS	8	**	ns	***	***	ns
VxL	1	***	ns	***	ns	ns
SxL	8	***	ns	***	ns	ns
VxSxL	8	***	ns	***	ns	ns
Residuals	68					
CV (%)		12.18	29.43	11.30	7.8	22.55

** and *** shows significance level of the F-test for the different parameters, while "ns" is non-significant. MFLY=Marketable fresh leaf yield, UFLY=Unmarketable fresh leaf yield, TFLY= Total fresh leaf yield, FLWPP=Fresh leaf weight per plant, LDW= Leaf dry weight.

RESULTS AND DISCUSSION

All parameters except unmarketable leaf yield were significantly influenced by the individual effect of spacing, variety, location and their interaction, while the leaf dry weight percent was varied by variety only (Table 2).

The interaction of spacing and variety significantly affected fresh leaf yield (marketable and total, t ha^{-1}) and leaf fresh weight (g $plant^{-1}$) while unmarketable fresh leaf yield and leaf dry weight were not significantly affected by the interaction (Table 3). Nevertheless, the latter two parameters were significantly affected by the main effect

Table 3. Interaction of plant spacing and variety on fresh leaf yield and leaf dry weight of lettuce (combined over location and year).

Variety	Spacing (cm × cm)	Planting Density (plants ha^{-1})	MFLY (t ha^{-1})	UFLY (t ha^{-1})	TFLY (t ha^{-1})	FLWPP (g)	LDW (%)
Great Lakes	30x20	166667	42.69^{d}	3.57	46.26^{d}	694.43^{cd}	1.87
	40x20	125000	67.80^{a}	2.69	70.49^{a}	811.13^{a}	2.33
	30x30	111111	47.65^{c}	4.96	52.61^{c}	875.91^{ab}	2.08
	50x20	100000	64.38^{a}	1.22	65.60^{b}	575.46^{e}	1.87
	40x30	83333	52.47^{b}	0.89	53.36^{c}	652.51^{d}	1.77
	30x40	83333	37.41^{e}	3.48	40.89^{e}	640.49^{de}	2.11
	50x30	66667	48.64^{bc}	2.05	50.69^{cd}	895.13^{a}	1.44
	40x40	62500	38.98^{de}	1.33	40.31^{e}	905.93^{a}	1.66
	50x40	50000	36.67^{e}	0.71	37.39^{e}	720.42^{c}	1.54
Mean			48.52	2.32	50.84	752.38	1.85
Rsk-3 (Red lettuce)	30x20	166667	27.15^{f}	0.95	28.11^{f}	210.27^{g}	3.53
	40x20	125000	21.93^{g}	0.80	22.73^{g}	178.29^{gh}	4.52
	30x30	111111	19.83^{gh}	1.56	21.39^{gh}	214.75^{g}	7.81
	50x20	100000	19.55^{gh}	0.71	20.26^{gh}	334.72^{f}	4.47
	40x30	83333	17.92^{ghi}	1.14	19.06^{ghi}	342.66^{f}	4.20
	30x40	83333	14.79^{i}	0.67	15.45^{i}	129.31^{h}	7.33
	50x30	66667	17.78^{ghi}	0.63	18.41^{ghi}	341.02^{f}	6.90
	40x40	62500	14.71^{i}	0.76	15.47^{i}	332.13^{f}	8.70
	50x40	50000	16.89^{hi}	0.63	17.52^{hi}	238.50^{g}	6.11
Mean			18.95	0.87	19.82	257.96	5.95
	CV		12.18	29.43	11.30	7.80	22.55
	LSD (5%)		4.74	2.19	4.59	65.42	8.03
	Significance		**	ns	***	***	ns

Means within a column having the same letters are not significantly different. *, **, *** Significant, highly significant and very highly significant at 5% level respectively. MFLY=Marketable fresh leaf yield, UFLY=Unmarketable fresh leaf yield, TFLY= Total fresh leaf yield, FLWPP=Fresh leaf weight per plant, LDW= Leaf dry weight.

of variety (Table 4). The highest total fresh leaf yield (70.49 t ha^{-1}) was obtained at 40 cm x 20 cm (125,000 plants ha^{-1}) from variety Great Lakes followed by 65.60 t ha^{-1} at 50 cm x 20 cm (100,000 plants ha^{-1}) and 53.36 t ha^{-1} at 40 cm x 30 cm (83,333 plants ha^{-1}), while the least (37.39 t ha^{-1}) was resulted from the wider spacing of 50 cm x 40 cm (50,000 plants ha^{-1}). The highest fresh leaf yield (28.11 t ha^{-1}) of Rsk-3 was obtained at 30 cm x 20 cm (166,667 plants ha^{-1}) followed by 22.73 t ha^{-1} at 40 cm x 20 cm (125,000 plants ha^{-1}), which continued to decrease with decreasing planting densities (wider spacing). The highest fresh yield obtained from Rsk-3 was 60% less than the highest yield obtained from Great Lakes.

Variety Rsk-3 was found to be inferior in total fresh leaf yield and fresh leaf weight plant^{-1} than Great Lakes in all the spacing treatments; however, both varieties exhibited significant increase in fresh leaf yields with increasing planting density (Figure 2). Regardless of the overall differences in fresh leaf yield performance between the two lettuce varieties, both responded positively to increasing planting density. Leaf fresh yield increased with increasing planting density although the trend varied (Figure 2) and was positive and significant (R^2=0.60 for Great Lakes and R^2=0.89 for Rsk-3). In the case of variety Great Lakes, the increment started to drop after the planting density reached 125,000 plants ha^{-1} (40 cm x 20 cm) at which the maximum yield was attained whereas variety Rsk-3 showed no sign of dropping after attaining its maximum yield (Figure 2). It was observed that closely spaced plants grow very fast as compared to wider spaced plants. This is mainly the result of competition for photosynthetic active radiation which stimulates growth and increased total yield parameters (Maboko and Du Plooy, 2009).

In case of Great Lakes, the highest fresh leaf yield was obtained at 125,000 plants ha^{-1} due to the larger number of heads harvested; however, at higher density (166,667 plants ha^{-1}), yields started to drop again due to the fact that at higher density size of individual heads reduced although the number is high. On the other hand, regardless of the increasing planting density, Rsk-3 did

Table 4. Average fresh leaf yield, and dry weight performance of the main effect of spacing and variety over locations.

Spacing (cm × cm)	Planting density (plants ha^{-1})	MFLY (t ha^{-1})	UFLY (t ha^{-1})	TFLY (t ha^{-1})	FLWPP (g)	LDW (%)
			Spacing			
30x20	166667	34.92^{b}	2.26	37.18^{c}	452.35^{c}	2.70
40x20	125000	44.87^{a}	1.74	46.61^{a}	495.02^{c}	3.42
30x30	111111	33.74^{b}	3.26	36.99^{c}	545.33^{b}	4.94
50x20	100000	41.96^{a}	0.97	42.93^{b}	455.09^{c}	3.17
40x30	83333	33.63^{b}	0.78	34.41^{c}	497.58^{c}	2.99
30x40	83333	27.66^{c}	2.31	29.97^{d}	384.90^{d}	4.72
50x30	66667	33.21^{b}	1.34	34.55^{c}	618.07^{a}	4.17
40x40	62500	26.85^{c}	1.05	27.89^{d}	619.03^{a}	5.18
50x40	50000	26.78^{c}	0.67	27.45^{d}	479.46^{c}	3.82
	LSD (5%)	3.25	4.66	3.25	46.26	5.34
	Significance	**	ns	**	***	ns
			Variety			
Great Lakes		48.52^{a}	2.32^{a}	50.84a	752.45^{a}	1.85^{b}
Rsk-3 (Red lettuce)		18.95^{b}	0.87^{b}	19.82^{b}	257.96^{b}	5.95^{a}
	LSD (5%)	1.53	0.73	1.53	21.81	0.49
	Significance	***	**	***	***	***
	CV	12.18	29.43	11.30	7.80	22.55

Means within a column having the same letters are not significantly different. *, **, *** Significant, highly significant and very highly significant at 5% level respectively. MFLY=Marketable fresh leaf yield, UFLY=Unmarketable fresh leaf yield, TFLY= Total fresh leaf yield, FLWPP=Fresh leaf weight per plant, LDW= Leaf dry weight.

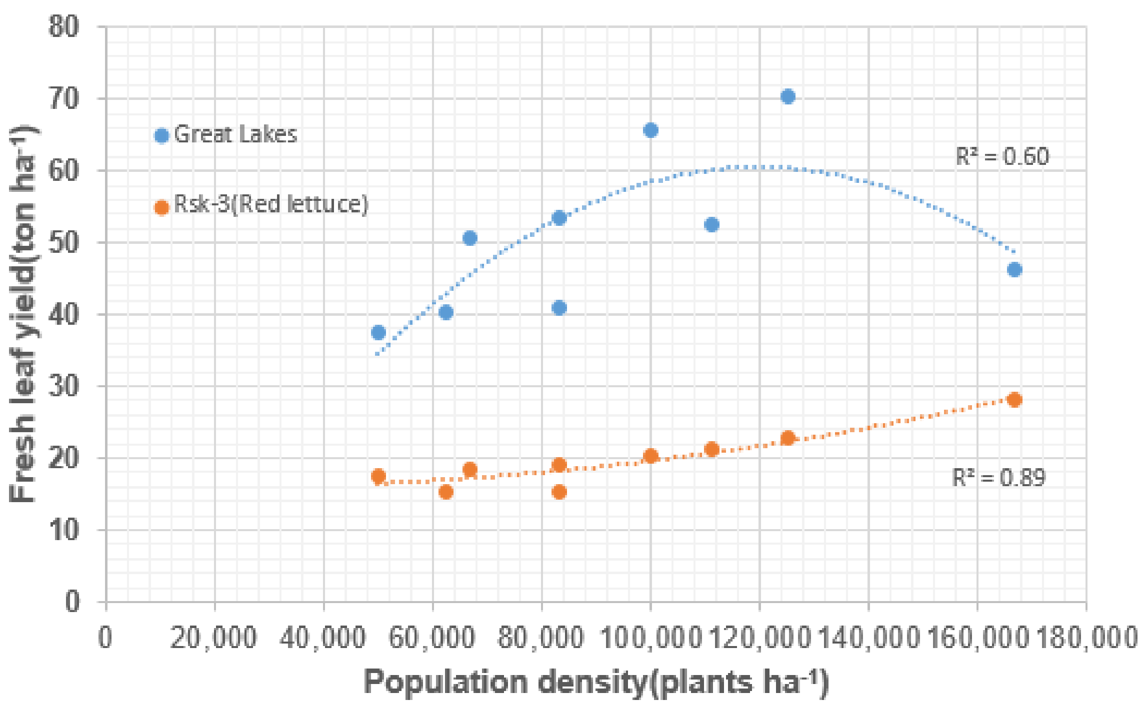

Figure 2. Responses of total fresh leaf yield (t ha^{-1}) of Great Lakes and Rsk-3 to increasing planting density.

not show yield dropping. This could be due to the fact that the plant densities used in the study did not reach the level at which Rsk-3 responds to reach its maximum yield.

The higher number of plants at the closer spacing contributed to higher fresh leaf and dry mass per unit area of lettuce compared to wider spacing, while a tendency of increased fresh leaf and dry mass per unit area was obtained as the plant spacing decreases (Maboko and Du Plooy, 2009). According to Maboko and Du Plooy (2009), although on different lettuce cultivars and locations, planting density significantly affected different growth and yield parameters including fresh and dry leaf mass, with significantly higher values of all variables at the closest spacing 10 cm x 20 cm (50 plants m^{-2}). The results indicate that an increase in planting density results in a significant increase in yield and yield components of leafy lettuce. This holds true mainly for our leafy lettuce Rsk-3 variety in the present study, which gave the highest fresh leaf yield at a higher density (17 plants m^{-2}) at 30 cm x 20 cm (166,667 plants ha^{-1}).

Cultivar differences observed were mostly due to differences on fresh mass, higher leaf area, plant height and leaf number (Maboko and Du Plooy 2009), although the latter three parameters were not included in the present study The higher fresh leaf yield obtained in the present study was also from the closest spacing 40 cm x 20 cm (13 plants ha^{-1}) for Great Lakes and 30 cm x 20 cm (17 plants ha^{-1}) for Rsk-3, although the spacing used in this study was wider (low plant density) compared to what was used in Maboko and Du Plooy (2009). A related study conducted on variety “Tesfa Mekele” in Tigray region showed similar results of the increasing trend of fresh leaf biomass with increasing plant density (Beyenesh et al., 2017) in which the highest leaf biomass was obtained at 60 cm x 40 cm spacing (4 plants ha^{-1}), although it is wider compared to the present study. A spacing of 30 cm x 30 cm (11 plants ha^{-1}) gave the highest fresh weight of leaves in an experiment conducted on Great Lakes in Ghana (Abdul-Halim et al., 2011), which is much more closer to our results as both studies are on the same variety-Great Lakes. Abdul-Halim et al. (2011) also found 1.254% of leaf dry weight at 30 cm x 30 cm from Great Lakes although spacing did not affect leaf dry weight in our study, but similar average leaf dry mass (1.85%) (Table 3). A spacing of 40 cm x 25 cm (10 plants ha^{-1}) gave the maximum yield (7.68 t ha^{-1}) on cultivar Grand Ratids in Bangladesh, which is of course small yield compared to ours, although the highest yield from variety Great Lakes in the present study was obtained at this plant density (40 cm x 20 cm), but different variety (Alahi et al., 2014).

Great Lakes was superior in fresh leaf weight $plant^{-1}$ over Rsk-3 (Table 3). The average fresh leaf weight $plant^{-1}$ of Great Lakes was 752.45 g ranging from 575.4 to 905.93 g, while the highest weight was obtained at 40 cm x 40 cm (62,500 plants ha^{-1}) and the least was at 50 cm x 20 cm (100,000 plants ha^{-1}). However, the average fresh leaf weight $plant^{-1}$ obtained from Rsk-3 was only 257.96 g at 40 cm x 30 cm (83,333 plants ha^{-1}) which is three times less than that of the Great Lakes (752.45 g). The maximum fresh weight of lettuce plant was observed from 40 cm × 30 cm while the minimum fresh weight per plant was found from 40 cm × 20 cm (Hasan et al., 2017).

Genetic differences between the varieties (compactness, head size, growth habit, etc) could be the reason for this much differences in fresh yield performances. Great Lakes is headed type lettuce and has compacted/folded leaves which contributed to having a higher weight per plant and total fresh yield, while Rsk-3 is loose and open non heading type which could result in a reduced fresh weight per plant and total fresh yield. Variations in genetic makeup between lettuce varieties made differences in yield contributing components such as leaf area, plant height, number of leaves that would create differences in fresh weight per plant and total fresh yield per unit area (Maboko and Du Plooy, 2009). Besides, unlike the total fresh leaf yield (t ha^{-1}), increasing planting density decreased fresh leaf weight per plant in both varieties (in other words, increasing plant spacing increased fresh weight $plant^{-1}$) (Figure 3).

Our results are in agreement with similar studies which revealed that fresh weight $plant^{-1}$ of lettuce showed statistically significant variation due to different plant spacing. The increases of spacing showed increasing trend in fresh weight of plant. In case of wider spacing, plants receive enough light and nutrients which leads to attaining maximum fresh weight of plant (Rincon et al., 1998; Tittonell et al., 2003; Boroujerdnia and Ansari, 2007). Hence, optimum plant spacing ensured maximum vegetative growth that ensured highest fresh weight $plant^{-1}$ (Hasan et al., 2017).

Although spacing did not affect the leaf dry weight of both varieties, varietal differences was obtained. Rsk-3 (5.95%) was better in dry weight percent than Great Lakes (1.85%) unlike the other parameters such as total fresh leaf yield and fresh leaf weight per plant (Table 4). Significant interaction between variety and spacing treatments was also observed over locations in most of the parameters measured (Table 5). Great Lakes performed better at Debrezeit than at Holeta and Rsk-3 did well at Holeta than at Debrezeit at all spacing treatment combinations (Table 5). In particular, the total fresh leaf yield performance of Great Lakes at Debrezeit (106.58 t ha^{-1}) was three-fold higher than at Holeta (34.41 t ha^{-1}) at optimum planting density (125000 plants ha-1) while Rsk-3 was better at Holeta (30.02 t ha-1) than at Debrezeit (26.19 t ha-1) at planting density of 166,667 plants ha^{-1} although this difference was not as high as observed in Great Lakes between the locations.

Nevertheless, the average yield performance of Great Lakes over the spacing treatments at Debrezeit was 71.79 t ha^{-1}, which was still superior over its performance at Holeta (29.90 t ha^{-1}). On the other hand, the average

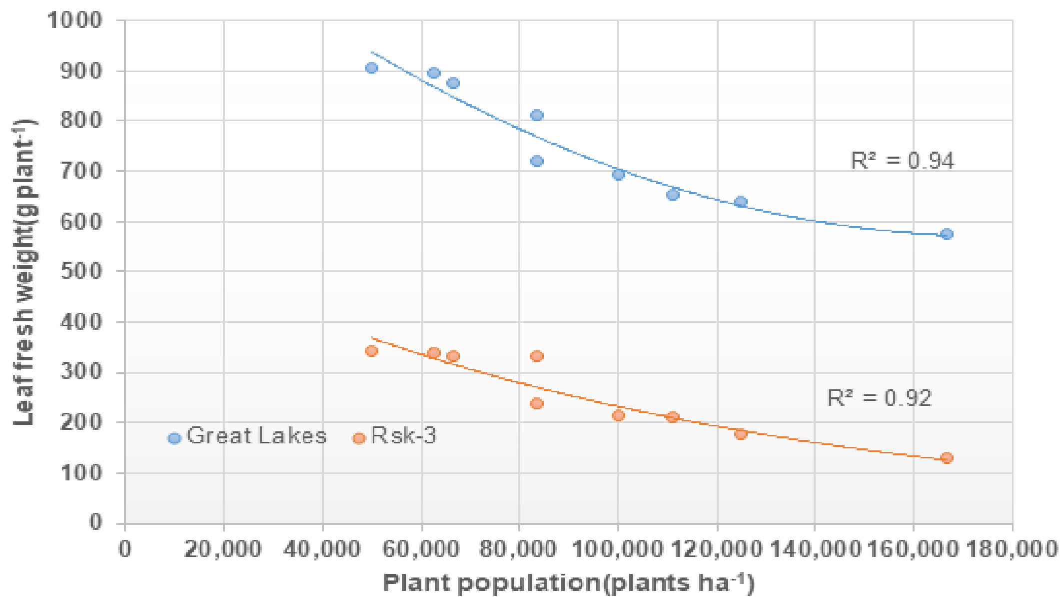

Figure 3. Responses of fresh leaf weight (g plant^{-1}) of Great Lakes and Rsk-3 to increasing planting density.

Table 5. Interaction effect of variety and spacing on fresh leaf yield of individual location.

Variety	Spacing (cm × cm)	Planting density (plants ha^{-1})	MFLY(t ha^{-1}) Debrezeit	Holeta	UMFLY(t ha^{-1}) Debrezeit	Holeta	TTFLY (t ha^{-1}) Debrezeit	Holeta
	30x20	166,667	57.30^{d}	28.08^{abc}	4.84	2.29	62.16^{c}	30.37^{abc}
	40x20	125,000	103.61^{a}	31.99^{a}	2.96	2.42	106.58^{a}	34.41^{a}
	30x30	111,111	66.83^{c}	28.48^{abc}	7.75	2.17	74.58^{b}	30.64^{abc}
	50x20	100,000	101.81^{a}	26.94^{bcde}	0.21	2.22	102.03^{a}	29.16^{abcd}
Great Lakes	40x30	83,333	77.34^{b}	27.6^{abcd}	1.16	0.61	78.50^{b}	28.21^{bcde}
	30x40	83,333	49.44^{de}	25.38^{cde}	5.07	1.89	54.51^{cd}	27.27^{bcde}
	50x30	66,667	69.26^{bc}	28.02^{abc}	2.64	1.46	71.90^{b}	29.49^{abcd}
	40x40	62,500	47.43^{e}	30.53^{ab}	0.98	1.67	48.42^{d}	32.20^{ab}
	50x40	50,000	47.04^{e}	26.30b^{cde}	0.37	1.05	47.41^{d}	27.36^{bcde}
		Mean	**68.90**	**28.15**	**2.89**	**1.75**	**71.79**	**29.90**
	30x20	166,667	25.08^{f}	29.23^{abc}	1.12	0.79	26.19^{e}	30.02^{abc}
	40x20	125,000	18.52^{fgh}	25.35^{cde}	0.42	1.17	18.94^{efg}	26.52^{cde}
	30x30	111,111	13.50^{ghi}	26.16^{bcde}	2.27	0.85	15.77^{fgh}	27.01^{bcde}
Rsk-3 (Red lettuce)	50x20	100,000	21.46^{fg}	17.64^{f}	0.00	1.42	21.46^{ef}	19.06^{fg}
	40x30	83,333	11.97^{hi}	17.60^{f}	0.64	0.69	12.61^{ghi}	18.30^{g}
	30x40	83,333	11.29^{hi}	24.54^{cd}e	1.10	1.17	12.40^{ghi}	25.72^{cde}
	50x30	66,667	12.66^{hi}	22.90^{de}	0.00	1.26	12.66^{ghi}	24.16^{def}
	40x40	62,500	7.47i	21.95^{ef}	0.57	0.95	8.05^{i}	22.90^{efg}
	50x40	50,000	9.35i	24.42^{cde}	0.00	1.27	9.35^{hi}	25.69^{cde}
		Mean	**14.59**	**23.31**	**0.68**	**1.06**	**15.27**	**24.37**
	CV		11.86	11.82	34.41	43.05	10.59	12.01
	LSD (5%)		8.22	5.04	9.04	4.43	7.65	5.41
	Sig.		***	*	ns	ns	***	*

Means within a column having the same letters are not significantly different. *, **, *** Significant, highly significant and very highly significant at 5% level respectively. MFLY=Marketable fresh leaf yield, UFLY=Unmarketable fresh leaf yield, TFLY= Total fresh leaf yield.

yield performance of Rsk-3 was better at Holeta (24.37 t ha^{-1}) than at Debrezeit (15.27 t ha^{-1}) (Table 5). Lettuce is considered a crop of mild climate and its production in regions of low altitude is impaired due to the high temperatures and the predominance of long days (Cardoso et al., 2018). Using the results of the present study, it is possible to suggest that the different varieties respond differently to different agro-ecologies, depending on their adaptation. Hence, based on the results obtained in the present study, Great Lakes preferred relatively a mid-low altitude and warm temperature of Debrezeit compared to Rsk-3 which rather preferred a higher altitude and cooler environment of Holeta.

CONCLUSIONS AND RECOMMENDATION

Based on the results of the present study, marketable and total fresh leaf yield, fresh leaf weight per plant and dry weight were significantly affected by the main effect of plant spacing and variety as well as its interaction. Increasing planting density increased the total fresh leaf yield per unit area in both varieties; but reduced the fresh leaf weight per plant. Variety Great Lakes was superior over Rsk-3 in total fresh leaf yield as well as fresh leaf weight per plant. However, leaf dry weight of Rsk-3 was higher than that of Great Lakes although spacing did not affect the leaf dry weight of both varieties. Besides, both lettuce varieties responded differently in both sites while Great lakes performed better at Debrezeit than at Holeta, and Rsk-3 did well at Holeta than at Debrezeit. Nevertheless, increasing leaf yield at higher plant densities should conform with the quality attributes such as head size, plant weight and etc as it may have high implication for consumer preferences as far as lettuce is considered, while too small or too large-sized lettuce head is not usually preferred by consumers. It should be noted that the results presented here are only for the data collected in the experimental season with irrigation and cannot be extrapolated to other production systems and production seasons. Whether the increased plant density will affect head size, leaf numbers, leaf area, growth season, etc will be investigated in future studies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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