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VARIETAL STABILITY, YIELD AND QUALITY PERFORMANCE OF LONG RADISH (*Raphanus sativus* var. *longipinnatus* L.) IN MID COUNTRY WET ZONE OF SRI LANKA

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ABSTRACT

Along with the increasing trend of tourism in Sri Lanka, there is a growing demand for radish varieties suitable for salads especially from hotel industries. The locally recommended radish varieties, *Beeralu* and Japanese ball, are not appropriate to this requirement. Though few exotic long radish varieties are cultivated in Up Country, their adaptability in other regions is poorly understood. Aiming to select high yielding, low pungency varieties adaptable to Mid Country Wet Zone climatic conditions, three Korean long radish varieties were evaluated along with the existing exotic radish variety, *Green bow*, for four consecutive seasons. Randomized Complete Block Design was used with three replicates. Yield and quality performances and stability parameters for single plant weight, single root weight and total yield were recorded. There were differences among the varieties for root length, root circumference, single plant weight, single root weight and total yield. Varieties, *Supergiljo* (53.2 t/ha) and *Yeongdong* (52.5 t/ha) had given higher yield. Higher stability for single plant weight (D = 0.252 and 0.113), root weight (D = 0.182 and 0.120) and total yield (D = 4.875 and 7.367) over seasons indicates their adaptability for Mid Country Wet Zone. Highest median value and sum of ranks in the sensory evaluation revealed the suitability of *Yeongdong* and *Supergiljo* for salad purposes.

Key words: Adaptability, Radish, Sensory evaluation, Stability, Yield

INTRODUCTION

Radish, *Raphanus sativus* L. is grown for its tender tuberous roots which are eaten raw as salad or cooked as a vegetable. It is relished for a pungent flavour and is considered as an appetizer. Young leaves are also used for culinary purposes. Radish has comparatively moderate nutritive values (Lorenz and Maynard, 1980) and is a popular choice for cultivation as it is fairly easy to grow with many varieties reaching maturity within 60 days.

Radish can be grown throughout the year in Sri Lanka. *Beeralu* and Japanese ball are the two locally recommended varieties presently cultivated in low and up country, respectively. Along with the increasing trend of tourism, the hotel industries and super market chains seek radish varieties suitable for salad purposes to cater the demand. However, local radish varieties are not appropriate for the purpose as they do not fulfil the requirement. At present, few exotic salad varieties are being cultivated in up country Wet zone. However, their suitability for other regions where ambient temperature is relatively high is not known. Hence, identification of suitable varieties for other areas is a need to meet the growing demand of the crop. On the other hand, low pungent radish is an important vegetable in East Asian countries and is consumed mostly as salads and some other uncooked forms. Hence, evaluation of varieties that are developed elsewhere may help to introduce such varieties within a short span of time.

Stability of a genotype is defined as a function of yield variation due to changing environmental factors across either locations or seasons or both (Abeysiriwardena *et al*., 1991). Assessment of stability parameters is necessary to identify phenotypically stable genotypes. The characterization of stable accession is often complicated by the frequent occurrence of genotype x environment interactions (GEI) (Cervenski *et al*., 2011). Several stability analyses have been proposed to recommend accessions that perform consistently better across different environments (Bernardo, 2002). A proper understanding of the magnitude and nature of GEI and stability of the complex traits, yield and yield components would help in identification of stable varieties.

Hence, a study was carried out to evaluate yield, quality and stability performances of Korean long radish varieties (*Raphanus sativus* var. *longipinnatus* L.) aiming to select high yielding low pungent salad varieties suitable to Mid Country Wet Zone of Sri Lanka.

MATERIALS AND METHODS

A series of field experiments were conducted during four consecutive seasons from 2012 to 2013 at the Horticultural Crops Research and Development Institute, Gannoruwa, Peradeniya (Mid Country Wet Zone). Elevation of the experiment site is 510 m above mean sea level and the mean day and night temperature were 28 ºC and 25 °C, respectively. The soil type is reddish brown latosolic soil, which is suitable for long radish cultivation.

Three Korean long radish varieties, *Supergiljo*, *Yeongdong* and *Metjinmatdonamu*, were evaluated along with the popular exotic long radish variety, *Green bow* during two *Maha* (rainy) and *Yala* (hot) seasons. These varieties were arranged in a Randomized Complete Block design with three replicates. Seeds were sown at 60 cm x 25 cm in 4.5 x 3.5 m plots. Before planting, N 40 kg/ha as urea, P_2O_5 50 kg/ha as triple super phosphate, 40 kg K_2O as muriate of potash were applied to the plots. Three weeks after planting, N 40 kg/ha as urea and 40 kg K_2O as muriate of potash were applied. Pests and diseases were controlled as per the departmental recommendations. Plants were harvested at two months age. Yield components such as root length, root circumference, single plant weight (with leaves), single root weight (without leaves) and root/ leaf ratio (fresh weight basis) were recorded on five randomly selected plants per plot in addition to total yield.

Data were analysed using SAS 9.0 package to test the effects of variety, season and variety x seasonal interaction using two-way analysis of variance and means were separated by the least significant difference. Mean deviation across seasons and stability parameter derived by partitioning GEI variance into components were estimated to assess the stability of varieties (Abeysiriwardena *et al*., 1991). As the variety x season interaction was significant for most of the characteristics studied, detail tables are presented with their significance. Sensory evaluation for taste, colour, odour and overall acceptability of tested varieties were carried out with 15 unbiased panelist. Sensory data were analysed using Friedman Test.

RESULTS AND DISCUSSION

Yield performance

The popular exotic radish variety, *Green bow* had produced long roots (29.75 cm) than Korean varieties (Table 1). The Korean variety, *Supergiljo* produced the highest

mean root circumference (29.49 cm) while the lowest was observed in *Green bow* (21.08 cm; Table 2). The highest single plant weight (1.44 kg) was observed in *Supergiljo* followed by *Yeongdong* (1.3 kg) compared to other varieties (Table 3). Similar pattern was observed in tested varieties in respect to single root weight (Table 4). Highest root/leaf ratio (fresh weight basis) of 4.2 was recorded in *Yeongdong* and this could be attributed to higher root weight. Among the Korean varieties, the lowest root/leaf ratio of 3.40 was recorded in *Metjinmatdonamu* (Table 5). Differences in plant and root characters among varieties could be attributed to genetic make-up of the varieties.

Table 1. Seasonal and varietal variation in root length of radish during 2012-2013

Varieties	Root length (cm)						
	***Yala* 2012**	***Maha* 2012/13**	***Yala* 2013**	***Maha* 2013/14**	**Mean**	**CV %**	**Pr> F**
Supergiljo	23.2 ±1.8 $^{bc\,B}$	23.1 ±2.1 $^{b\,B}$	23.7 ±2.6 $^{b\,B}$	21.7 ±2.7 $^{a\,A}$	25.42	9.85	0.014
Yeongdong	23.8 ±0.8 $^{b\,A}$	21.8 ±1.6 $^{b\,A}$	21.5 ±2.2 $^{b\,A}$	23.6 ±1.1 $^{a\,A}$	22.98	6.24	0.200
Metjinmatdonamu	21.1 ±1.2 $^{c\,C}$	24.9 ±1.8 $^{ab\,B}$	24.3 ±1.1 $^{b\,B}$	29.9 ±1.3 $^{a\,A}$	25.05	5.93	0.002
Green bow (control)	31.4 ±1.7 $^{a\,A}$	29.0 ±3.5 $^{a\,A}$	23.3 ±3.2 $^{a\,A}$	28.5 ±4.5 $^{a\,A}$	29.75	9.82	0.651
CV %	4.55	10.23	7.18	8.61			
Pr> F	0.0001	0.053	0.005	0.205			

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 2. Seasonal and varietal variation in root circumference of radish during 2012-2013

Varieties	Root circumference (cm)						
	***Yala* 2012**	***Maha* 2012/13**	***Yala* 2013**	***Maha* 2013/14**	**Mean**	**CV%**	**Pr> F**
Supergiljo	28.0 ±4.3 $^{a\,B}$	25.2 ±1.8 $^{a\,B}$	29.0 ±2.8 $^{a\,B}$	35.6 ±0.2 $^{a\,A}$	29.49	9.98	0.023
Yeongdong	26.7 ±1 $^{ab\,B}$	23.2 ±0.3 $^{a\,C}$	28.1 ±2.3 $^{a\,B}$	34.5 ±1.8 $^{a\,A}$	28.16	4.84	0.003
Metjinmatdonamu	25.3 ±2.1 $^{a\,A}$	25.3 ±2.4 $^{a\,A}$	27.9 ±1.6 $^{a\,A}$	30.1 ±3.5 $^{a\,A}$	27.21	9.35	0.158
Green bow (control)	21.4 ±1.4 $^{b\,A}$	23.6 ±3.5 $^{a\,A}$	17.9 ±3.8 $^{b\,A}$	21.3 ±4.9 $^{b\,A}$	21.08	19.21	0.455
CV %	6.19	7.25	9.49	11.44			
Pr> F	0.009	0.391	0.004	0.008			

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 3. Seasonal and varietal variation in single plant weight of radish during 2012-2013

Varieties	Single plant weight (kg)						
	Yala 2012	*Maha* 2012/13	*Yala* 2013	*Maha* 2013/14	Mean	CV%	Pr> F
Supergiljo	1.23 ^{aC}	0.72 ^{abC}	1.36 ^{aB}	2.25 ^{aA}	1.39	22.68	0.006
Yeongdong	1.27 ^{aB}	0.59 ^{bC}	0.98 ^{bC}	2.36 ^{aA}	1.3	15.34	0.002
Metjinmatdonamu	1.00 ^{aA}	0.83 ^{aA}	1.23 ^{abA}	1.70 ^{aA}	1.19	28.32	0.077
Green bow (control)	1.00 ^{aA}	0.66 ^{abA}	0.87 ^{bA}	0.75 ^{bA}	0.82	18.73	0.128
CV %	18.97	14.91	16.06	18.86			
Pr> F	0.335	0.136	0.015	0.003			

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 4. Seasonal and varietal variation in single root weight of radish during 2012-2013

Varieties	Single root weight (kg)						
	Yala 2012	Maha 2012/13	Yala 2013	Maha 2013/14	Mean	CV%	Pr> F
Supergiljo	0.93 ^{aC}	0.54 ^{aD}	1.17 ^{aB}	1.81 ^{aA}	1.11	21.16	0.003
Yeongdong	0.93 ^{aB}	0.51 ^{aD}	0.79 ^{bcC}	1.98 ^{aA}	1.05	13.30	0.001
Metjinmatdonamu	0.70 ^{aA}	0.61 ^{aA}	1.03 ^{abA}	1.36 ^{bA}	0.92	30.66	0.060
Green bow (control)	0.77 ^{aA}	0.56 ^{aA}	0.62 ^{cA}	0.59 ^{cA}	0.63	12.96	0.081
CV %	18.86	13.29	14.32	20.85			
Pr> F	0.263	0.448	0.007	0.005			

Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 5. Mean values of root/ leaf ratio (fresh weight basis) of tested varieties during 2012-2013

Variety	Root/ leaf ratio
Supergiljo	3.96 + 1.4
Yeongdong	4.20 + 1.5
Metjinmatdonamu	3.40 + 1.2
Green bow (control)	3.31 + 1.3

It has been reported that the optimal temperature for the production of dry matter was 20 ^{0}C for radish and the dry matter content is highly influenced by temperature changes (Nieuwhof, 1976). *Green bow* is the variety usually, cultivated in Up Country

climatic conditions. It was observed that variety *Green bow* flowers under Mid Country climatic conditions before reaching maturity when high temperature prevailed. This could be attributed to the lower yield in *Green bow* during *Yala* season in Mid Country. However, the three Korean varieties, *Supergiljo*, *Yeongdong* and *Metjinmatdonamu* did not flower under high temperature conditions, and had produced higher yields throughout the year. Capecka (2001) and Kaymak *et al*. (2010) also observed that dry matter contents of radish varied depending on varieties and different varieties showed their optimum performance at different soil and climatic conditions. Higher incidences of *Erwinia* soft rot disease in *Green bow* than the Korean varieties during the tested seasons could also be attributed to lower total yield in *Green bow*.

The Korean variety *Supergiljo* gave the highest mean yield of 53.20 t/ha followed by *Yeongdong* (52.55 t/ha) while the popular variety, *Green bow* yielded the lowest (34.67 t/ha; Table 6). *Green bow* continuously gave statistically lower yield compared to some Korean varieties in the tested location.

Table 6. Seasonal and varietal variation in total yield of radish during 2012-2013

Variety	Yield (t/ha)						
	***Yala* 2012**	***Maha* 2012/13**	***Yala* 2013**	***Maha* 2013/14**	**Mean**	**CV%**	**Pr> F**
Supergiljo	54.22 ^{aA}	54.71 ^{aA}	51.2 ^{aA}	52.69 ^{aA}	53.20	18.71	0.326
Yeongdong	52.32 ^{aA}	52.57 ^{aA}	51.1 ^{aA}	54.23 ^{aA}	52.55	10.28	0.401
Metjinmatdonamu	49.86 ^{aB}	53.28 ^{aA}	48.1 ^{aB}	41.68 ^{bC}	48.23	21.79	0.037
Green bow (control)	33.50 ^{bB}	43.71 ^{bA}	22.3 ^{bC}	39.18 ^{bA}	34.67	22.28	0.006
CV %	11.32	14.42	17.18	16.27			
Pr> F	0.011	0.004	0.002	0.040			

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at $P \geq 0.05$ level

Except root length for *Metjinmatdonamu*, there was no significant variation in root length, root circumference, single plant weight and single root weight among *Yala* and *Maha* seasons irrespective to varieties at $P \geq 0.05$ (Tables 7, 8, 9 and 10). There was no significant yield difference in *Supergiljo*, *Yeongdong* and *Metjinmatdonamu* among seasons (Table 11). In contrast, *Green bow* gave significantly higher yields during *Maha* (41.44 t/ha) than *Yala* (27.9 t/ha) in the pooled analysis.

Table 7. Varietal variation in root length of radish over seasons

Varieties	Root length (cm)			
	Yala	***Maha***	**CV %**	**Pr> F**
Supergiljo	23.4 ^{bA}	22.4 ^{aA}	15.46	0.439
Yeongdong	22.6 ^{bA}	22.7 ^{aA}	22.51	0.182
Metjinmatdonamu	22.7 ^{bB}	27.4 ^{aA}	6.69	0.004
Green bow (Control)	27.3 ^{aA}	28.7 ^{aA}	10.49	0.332
CV %	8.58	12.78		
Pr> F	<0.001	0.894		

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 8. Varietal variation in root circumference of radish over seasons

Varieties	Root circumference (cm)			
	Yala	***Maha***	**CV%**	**Pr > F**
Supergiljo	28.5 ^{aA}	30.4 ^{aA}	14.85	0.475
Yeongdong	27.4 ^{aA}	28.8 ^{aA}	14.40	0.567
Metjinmatdonamu	26.6 ^{aA}	27.7 ^{aA}	7.98	0.420
Green bow (control)	19.6 ^{bA}	22.4 ^{bA}	14.76	0.711
CV%	10.80	16.86		
Pr > F	0.001	0.011		

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 9. Varietal variation in single plant weight of radish over seasons

Varieties	Single plant weight (kg)			
	Yala	***Maha***	**CV%**	**Pr > F**
Supergiljo	1.29 ^{aA}	1.48 ^{aA}	15.24	0.475
Yeongdong	1.12 ^{aA}	1.47 ^{aA}	11.66	0.567
Metjinmatdonamu	1.11 ^{aA}	1.26 ^{aA}	13.01	0.421
Green bow (control)	0.93 ^{aA}	0.70 ^{bA}	21.97	0.075
CV%	16.66	15.71		
Pr> F	0.108	0.02		

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 10. Varietal variation in single root weight of radish over seasons

Variety	Single root weight (kg)			
	Yala	***Maha***	**CV%**	**Pr > F**
Supergiljo	1.05 $^{a A}$	1.17 $^{a A}$	19.55	0.635
Yeongdong	0.86 $^{a A}$	1.24 $^{a A}$	10.23	0.621
Metjinmatdonamu	0.87 $^{a A}$	0.98 $^{ab A}$	13.32	0.530
Green bow (Control)	0.69 $^{a A}$	0.57 $^{a A}$	17.79	0.137
CV%	15.40	17.91		
Pr > F	0.108	0.02		

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Table 11. Varietal variation in total yield of radish over seasons

Variety	Yield (t/ha)			
	Yala	***Maha***	**CV%**	**Pr > F**
Supergiljo	52.7 $^{ab A}$	53.70 $^{a A}$	14.42	0.2191
Yeongdong	51.7 $^{a A}$	53.40 $^{a A}$	15.48	0.2064
Metjinmatdonamu	48.9 $^{a A}$	47.48 $^{ab A}$	23.32	0.1544
Green bow (Control)	27.9 $^{b A}$	41.44 $^{b B}$	26.76	0.0191
CV %	22.60	19.89		
Pr > F	0.0752	0.0173		

Note: Mean values followed by different lowercase letters in a column and uppercase letters in a row are significantly different at P ≥ 0.05 level

Varietal Stability

The highest positive mean deviation (D) for single plant weight and root weight was recorded in *Supergiljo* followed by *Yeongdong* while the highest D was obtained in *Yeongdong* for total yield (Table 12). Except single plant weight, *Metjinmatdonamu* had revealed negative mean deviation for yield characters. All the Korean varieties had shown non-significant interaction (S^2) with environment for yield components. High positive D values and non-significant interaction for yield components obtained in *Supergiljo* and *Yeongdong* could be due to their genetic stability at diverse seasons. This is in accordance to Abeysiriwardena *et al*. (1991) that a stable genotype is one that has high positive mean deviation across environments and non-significant interaction with the environment. Negative mean deviation and significant interaction with the environment of all three

parameters shows the instability of *Green bow* as a radish variety under Mid Country climatic conditions.

Table 12. Mean deviation (D) and stability parameter (S_2) values for yield components during 2012-2013

Variety	Single plant weight		Single Root weight		Total yield	
	D	S_2	D	S_2	D	S_2
Supergiljo	0.252 [a]	0.101	0.182 a	0.055	4.875 [ab]	114.048
Yeongdong	0.113 [ab]	0.123	0.120 [ab]	0.086	7.367 [a]	111.803
Metjinmatdonamu	0.023 [b]	0.086	-0.005 [b]	0.067	-0.875 [b]	80.722
Green bow	-0.368 [c]	0.185*	-0.297 [c]	0.127*	-11. 342 c	157.671*

** Significant interaction with environment*

A single variety may not be suitable for all the agro-climatic regions, hence, different varieties have to be identified for specific regions and purposes. Selection of improved varieties suitable for specific environments is, therefore, an important factor to be considered when making varietal recommendations. Very few cultivars of radish are presently grown in Mid Country of Sri Lanka. Thus, selection of high yielding low pungency varieties adaptable to Mid Country Wet Zone climatic conditions is necessary to cater the growing demand.

Abeysiriwardena *et al*. (1991) defined stability of a genotype as a function of yield variation due to changing environmental factors across either locations or seasons or both. Genotypes performing well under a particular environment may or may not perform well over other environments due to genotype x environment interactions. A genotype with low GEI will have high stability. Therefore, both yield and stability of performance should be taken into consideration when selecting a high yielding cultivar.

Stability analysis of variance indicated differences among the varieties for yield components indicating presence of variability among varieties. Differences among seasons were indicated by the variability for yield characters. The characters single plant weight, single root weight and yield had varied response to environment. Similar findings were reported for radish by Sivathanu *et al*. (2015). The data indicated that variety *Supergiljo* exhibited stable performance on plant weight, root weight and yield followed by *Yeongdong* in all seasons. It showed the stability of these varieties for varying

environments. Thus, these varieties are suitable for the cultivation in Mid Country. Rest of varieties was influenced by environmental fluctuation and was unsuitable for prevailing climatic conditions of Mid Country.

Quality

The sensory evaluation of radish varieties for taste, colour, odour and overall acceptability is given in Table 13.

Table 13. Friedman test for Taste, Odour, Colour and overall acceptability of tested varieties during *Yala* 2013

Treatment	No of Participants	Taste		Odour		Colour		Overall acceptability	
		Est Median	Sum of ranks	Est Median	Sum of ranks	Est Median	Sum of ranks	Est Median	Sum of ranks
Supergiljo	15	4.0	52	3.2	48	3.2	44.0	3.8	113.0
Yeongdong	15	4.6	62	4.0	54	2.8	48.0	4.5	127.5
Metjinmatdonamu	15	2.4	35	2.4	38	2.0	39.0	2.5	78.0
Green bow	15	2.0	33	2.0	33	3.0	44.0	1.5	51.5
$P \geq F$		0.004		0.006		0.268		0.005	

According to Friedman test, the variety scored with the highest est median and highest sum of ranks is considered as the best variety. The Korean variety, *Yeongdong* scored the highest est median value (4.6) and highest sum of ranks (62) for taste followed by *Supergiljo* (4.0 est median value and 52 sum of ranks) while *Green bow* scored the lowest est median value (2.0) and sum of ranks (33). Similar results were obtained for odour where the lowest odour indicated by highest est median value and higher sum of ranks. There was no significant difference among the color according to the Friedman test. The variety, *Yeongdong* had shown the highest overall acceptability (sum of ranks 127.5 and est median 4.5). However, *Green bow*, the variety widely cultivated in UCWZ at present, scored the lowest overall acceptability, which was indicated by the lowest sum of ranks of 51.5 and lowest est median. Rod *et al*. (1999) reported that the predominant taste characteristic of white radish is its fresh pungent flavour which is caused by 4-methylthio-

3-trans-butenyl Isothiocyanate (MTBITC) and the concentration of MTBITC was the highest in the spring trial and the lowest in the autumn trial. Moreover, when radish is grown and harvested when temperature remains hot, it developed an increased bitterness.

Long rooted radish, mainly used for salad and decorative purposes, has high demand by hotel industry. At present, only a few exotic varieties are cultivated in Up Country for this purpose; however, their yield and quality performance has not been assessed in Mid Country so far. Both locally recommended varieties, Japan ball and *Beeralu*, are smaller in size and high in pungency. In this study, the Korean variety *Yeongdong* scored the highest est median and highest sum of ranks thereby could be considered as the best variety for good taste, lowest odor and overall acceptability. However, the existing popular variety, *Green bow* showed the lowest overall acceptability, which could be due to its slightly bitter taste and comparatively higher pungency. Hence, this variety might not be suitable for hotel industries when cultivating in Mid Country.

The findings of this study revealed that varieties, *Supergiljo* and *Yeongdong* had shown good yield and quality performances even when mean day and night temperature remains 28 ºC and 25 °C, respectively. Further, it showed stability for plant weight, root weight and yield over seasons in Mid Country.

CONCLUSION

Korean varieties, *Supergiljo* and *Yeongdong* had given higher yields (53.2 – 52.5 t/ha) and exhibited stable performance on plant weight, root weight and yield over seasons in mid country. Hence, these varieties could be considered as adaptable varieties under Mid Country Wet Zone climatic conditions. Furthermore, both Korean varieties scored highest median value and higher sum of ranks respectively for taste, colour, odour and overall acceptability in the sensory evaluation. Therefore, these varieties could be recommended to grown in Mid Country Wet Zone for salad purposes.

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