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Research Article

Performance Evaluation and Adaptability Study of Fodder Beet (*Beta vulgaris L.*) Cultivars in Highlands of Bale Zone South East Ethiopia

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Abstract

Shortage animal feed interims of quality and quantity is the major bottle neck in livestock production through the year in Ethiopia particularly in the highlands of Bale Zone. A study was conducted at Sinana Agricultural Research Center (SARC), South East Ethiopia for three consecutive cropping season (2020/21, 2021/22 and 2022/23) in two locations (Sinana on station and Agarfa subsite) to evaluate the adaptability of four Cultivars of Fodder beet (namely Bircks, Kulumsa, Magnum and Robbos). Experimental plots were laid out in a randomized complete block design with three replications. All cultivars were performed well. However, there is significant variation among the Cultivars. The combined result over locations over years indicated that, Kulumsa cultivars gives the highest shoot fresh biomass yield (41.88 t ha^{-1}), root fresh biomass yield (86.49 t ha^{-1}) and shoot Dry biomass yield (4.52 t ha^{-1}). The remaining cultivars have not statistically significant different. Based on the results of this study, it is concluded that the Fodder beet Kulumsa cultivars was found a promising in terms of grain and biomass yield, than others that could be demonstrated and popularized as an alternative feed resources under smallholder conditions in the study areas and with similar climatic and edaphic conditions.

Keywords

Fodder Beet, Improved Forage, Root Forage

1. Introduction

Livestock and especially ruminants are an essential component of most of the agricultural production systems in sub-Saharan Africa. Livestock is an integral component for most of the agricultural activities in Ethiopia. The livestock sector has a share of 12-16% of the total Gross Domestic Product (GDP), and 30-35% of agricultural GDP [4] Poor nutritive forage is the major causes of livestock productivity in smallholders' farms.

One option for improving the performance of low to medium intensity systems is the integration of crop sequences to improve the 'feed base' by incorporating forage crops which increase DM tonnage and feed efficiency [16]. Fodder beet used both above and below growth parts (leaves and roots) are used to feed the animals but, the main fodder is tuberous roots [10, 7] Fodder beet has been

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adopted as a winter forage, due to high yields (> 20 ton DM/ha) [5], of sugar dense and highly utilizable bulb. Its high content of carbohydrates per dry matters [1, 11] which is sown autumn and winter feeding of dairy herds grazed during late lactation and winter [3], or harvested and stored for 3 months above ground and fed as an early lactation source of water-soluble carbohydrate (WSC) in spring. However, the integration of complementary forages to circumvent seasonal herbage deficits can reduce profit and increase risk exposure, particularly during periods of climatic and economic adversity [8]. The extended growing season (> 200 days) and rotation length of FB (>12 months) increase the opportunity cost compared with that for alternative forage crops such as maize grown for silage, which has a shorter growing season (150 days) and can be reintroduced to the grazing rotation within six months [8].

In Ethiopia, adaptation and releasing of improved forage varieties done in different agro-ecologies. However, improved forage varieties were not well adopted in country; particularly in the study area especially fodder beet varieties not evaluated in highlands of Bale Zone. Therefore, the objective of this study was to select high biomass yield fodder Beet Cultivars for Highlands of Bale and similar agro-ecologies.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Bale Zone, Sinana on station that 463.3 km far from Addis Ababa and 33.3 km from Robe City in the South East. Its geographical location is 070 °7'N latitude and 40 °10'E longitude. An annual average of rainfall of 1174 mm. The area has bimodal rainfall pattern with distinct peaks in April and September [12]. Agarfa is Located at an elevation of 2466.75 m.a.s.l. The district's yearly temperature is 14.39 °C.

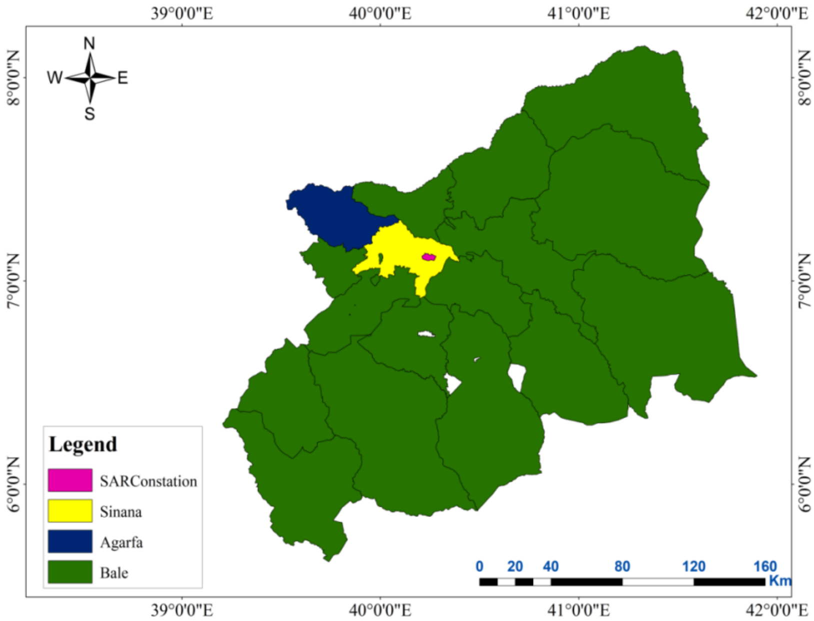

Figure 1. Map of the study areas of Sinana on station, Sinana and Agarfa district.

2.2. Treatments and Experimental Design

A total of four (4) Cultivars of Fodder beet Bircks, Kulumsa, Magnum and Robbos) were evaluated in RCBD with three replications. Plot size of 2 x 3m^2 was used. Seedling was raised on bed and transplanted to well-prepared arable land at spacing of 0.5 m between plants and between rows. Weeding and Hoeing was done accordingly.

2.3. Data Collection and Analysis

All relevant data including plant height (shoot and root length), dry shoot and Root biomass yield and Herbage shoot and root biomass were collected. Plant height: it was measured after 5 months when Biomass was taken root and shoots separately from five randomly taken plants and was averaged on per plant basis by using 50 cm Ruler.

Dry Fodder yield (shoot and root weight): five plants randomly taken from inner rows and manually harvested. It was taken after chopping into 5 cm - 8 cm length of 200 g for shoot, 500g and then oven dry at 35 °C for 48hrs weight and then converted tone per hectare based The dry matter production (t ha-1) was calculated as: - (10 x TotFWx (DWss/ HA x FWss)) [15]. Where: TotFW = total fresh weight from a plot in kg, DWss = dry weight of the sample in grams, FWss = fresh weight of the sample in grams, HA = Harvest area meter square and, 10 = is a constant for conversion of yields in kg /m^2 to t ha^{-1}. Data was analyzed using the Statistical Analysis Software to perform ANOVA (SAS 9.1). Means of all treatments were calculated and the difference was tested for significance using the least significant difference (LSD) test at $p < 0.05$ [9].

Statistical model was: $Yij = \mu + \tau i + \beta j + \varepsilon ijk$, where μ = the overall mean, τi = the treatment effect ith, βj = the block (replication) effect of jth replication and $\in ijk$ = error effect.

3. Results and Discussion

Growth Parameters, Yield Components and Yields

The results analysis of variance indicated significant different for total herbage dry matter yield of the four cultivars over two sites is shown in table 1. Root dry biomass and total dry biomass were significantly affected by the cultivars, location, and year with a significant interaction, so data for individual locations in each year are presented.

Table 1. *Mean squares of ANOVA for yields and yield components of Fodder beet cultivars.*

Source of variations	Mean squares							
	DF	**Shoot FBMY**	**Root FBMY**	**Root DBMY**	**Shoot DBMY**	**Total DBMY**	**Root Length**	**Shoot Length**
Cult	3	2142.8**	9102.40**	34.203*	10.82**	70.1**	147.291**	1079.5**
Loc	1	91.4NS	16500.3**	626.64**	0.4894NS	588.05**	88.674*	3414.5*
Yrs	2	10320*	23621.1**	447.026**	34.77**	580.74**	121.96**	9135.4**
Loc*Yrs	2	200.10*	22052.3**	835.352*	17.08	1072.6*	150.80**	10262.7*
Cult*Loc	3	52.4NS	882.8**	6.18NS	6.4974*	2.3NS	10.727*	111.3**
Cult*Yrs	6	861.6**	2235.4**	85.765**	1.6309NS	87.49**	13.475**	53**
Cult*Loc*Yrs	6	71*	1315.9**	57.016**	1.3396NS	71.57**	15.771**	55.6**
Error	120	27.1	131	6.063	0.7335	7.05	2.251	7

Loc= Locations, Cult=Cultivars, DF=Degree of freedom, FBMY= fresh biomass yield, DBMY=Dry Biomass yield in tone per hectare, * = significant different (0.05), ** = highly significant different (0.05), Yrs=years

3.1. Shoot Length

The mean performance of shoot length of *fodder beet* cultivars indicated in table 2. The mean shoot length were significant ($p < 0.05$) different among tested cultivars of fodder beet, the maximum Shoot length (56.2 cm) that obtained from Kulumsa cultivar followed by Bricks cultivar (51.27 cm) at Sinana on station.

Figure 2. Image of fodder beet during field conducted.

3.2. Root Length

The result of root length of fodder beet cultivars indicated shown in table 2. The mean of Root length were significant ($p < 0.05$) different among tested cultivars of fodder beet, the maximum Shoot length (22.80 cm) that obtained from Kulumsa cultivars followed by Robbos cultivars (20.68 cm) at Sinana and Agarfa locations respectively. The minimum root length obtained from Robbos cultivars (11.83 cm). Also the combined result of root length showed in table 2 significant variations with years and locations in addition to fodder beet cultivars. The maximum root length recorded in Agarfa location (17.92 cm) and third year (2022/23) (18.70 cm) whereas the minimum root length obtained in 2021/22 at Sinana on station (16.15 cm). This might be due to availability of rainfall condition in 2022/23 cropping season.

Table 2. The Mean of plant height of Fodder beet at different locations.

	Shoot length (cm)						**Root length (cm)**					
Treatments	**Sinana**			**Agarfa**			**Sinana**			**Agarfa**		
	2020/21	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**
Bricks	51.27a	45.57	61.37a	47.8b	51.41b	50.8b	12.93c	14.13a	14.93c	14.20c	15.96c	15.53c
Kulumsa	56.20a	45.8	61.00a	55.5a	58.28a	58.5a	20.13a	12.8b	22.80a	18.73a	20.03ab	20.73a
Magnum	45.00b	46.27	50.00b	42.2c	43.65c	45.2c	17.07b	12.1bc	19.07b	15.33b	18.71b	17.33b
Robbos	43.17b	46.37	48.27b	40.9c	45.48c	43.37c	17.27b	11.83c	19.27b	17.9ab	20.68a	19.9a
Grand Mean	48.91	46	55.12	46.60	49.705	49.47	16.85	12.717	19.02	16.54	18.84	18.38
CV (%)	2.61	9.6	2.6	7.21	11.31	7.09	10.83	5.63	8.84	5.39	6.71	6.01
LSD (0.05)	0.84	NS	0.83	1.94	1.95	2.02	1.06	0.41	0.97	0.52	0.73	0.64

Table 3. The Mean Dry biomass yields of fodder beet at sinana on station and Agarafa sub site for three consecutive cropping seasons.

	Shoot DBMY (t ha^{-1})						**Root DBMY (t ha^{-1})**					
Treatments	**Sinana**			**Agarfa**			**Sinana**			**Agarfa**		
	2020/21	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**	**2020/21**	**2021/22**	**2022/23**
Bricks	3.61b	2.06b	7.35c	2.74	3.69b	10.49c	10.4b	9.03a	4.30ab	7.50ab	22.065	4.44b

Treatments	Shoot DBMY (t ha^{-1})						Root DBMY (t ha^{-1})					
	Sinana			Agarfa			Sinana			Agarfa		
	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23
Kulumsa	5.38a	4.31a	10.99b	2.31	3.79b	20.13a	16.27a	6.24b	5.45a	7.09ab	20.163	5.86a
Magnum	3.57b	2.66b	15.85a	2.13	3.07c	14.69b	5.64c	8.62a	5.79a	6.01b	23.504	4.51b
Robbos	2.86b	2.63b	13.90a	2.37	4.28a	14.75b	10.65b	9.17a	3.21c	8.30a	19.503	4.56b
Grand Mean	3.85	2.91	12.02	3.39	3.71	15.013	10.74	8.27	4.69	7.22	21.309	4.8398
CV (%)	28.38	28.48	17.3	23	10.89	10.17	28.98	17.1	19.43	17.89	18.69	18.68
LSD(0.05)	0.63	0.48	1.2	NS	0.23	0.88	1.797	0.82	0.53	0.75	NS	0.53

Table 3*. Continued.*

Treatments	Total DHrY (t ha^{-1})					
	Sinana			Agarfa		
	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23
Bricks	14.00b	11.09	11.65c	10.24a	25.76	14.93c
Kulumsa	21.65a	10.55	16.44b	9.4ab	23.95	25.99a
Magnum	9.38c	11.27	21.64a	8.14b	26.58	19.20b
Robbos	13.51bc	11.79	17.11b	10.67a	23.78	19.30b
Grand Mean	14.64	11.18	16.71	9.61	25.01	19.853
CV (%)	25.99	15.22	10.52	25.99	16.09	9.14
LSD (0.05)	2.196	NS	1.02	0.95	NS	1.05

Table 4*. The Mean Fresh biomass yield of fodder beet at sinana on station and Agarafa sub site for three consecutive cropping seasons.*

Treatments	Shoot FBMY (t ha^{-1})					
	Sinana			Agarfa		
	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23
Bricks	21.31b	23.81b	35.73c	17.29	30.69c	35.60b
Kulumsa	30.94a	29.86a	68.13a	19.51	33.30ab	78.00a
Magnum	19.27b	22.83b	42.4b	16.09	23.47b	39.20b
Robbos	20.05b	22.77b	36.8c	17.83	37.95a	41.6b
Grand Mean	22.89	24.82	45.77	17.678	31.35	48.6
CV (%)	20.48	7.22	7.47	16.13	18.49	15.98
LSD (0.05)	2.71	1.03	1.97	NS	9.43	4.48

Table 4. Comtinued.

Treatments	Root FBMY (t ha^{-1}) Sinana			Agarfa		
	2020/21	2021/22	2022/23	2020/21	2021/22	2022/23
Bricks	46.56b	38.435	51.6c	30.69c	84.21b	53.6c
Kulumsa	70.15a	39.581	99.2a	33.30ab	129.92a	146.77a
Magnum	26.69c	36.221	77.07b	23.47b	96.28b	71.33b
Robbos	46.33bc	42.269	72.53b	37.95a	118.69a	77.33b
Grand Mean	47.43	39.13	75.1	31.35	107.27	87.26
CV (%)	34.42	15.9	5.25	18.49	16.84	8.77
LSD (0.05)	9.43	NS	4.35	9.43	10.43	4.41

ShootFBMY= Shoot Fresh Biomass yield, RootFBMY= Root Fresh Biomass yield, RootDBMY=Root Dry Biomass Yield, TotalDHrY=Total Dry Herbage Yield
Means with the same letter (a, b, c) in a column for parameters not significantly different (p > 0.05)

3.3. Fresh Shoot Biomass Yield and Root Biomass Yield

The combined analysis result shown in table 5. Fresh shoot biomass yield was significantly different ($P < 0.05$) among the treatments. The highest fresh shoot biomass yield (41.88 t ha^{-1}) and fresh root biomass (86.49 t ha^{-1}) was obtained from Kulumsa cultivars. However, among other cultivars of fodder beet statistically have not significant different. These results was consistent with those reported by [13] fresh shoot biomass yield and Similar ranges with [14] 84.23 to 106.04 t/ha and 7.11 to 15.00 t/ha, fresh and Dry herbage yield respectively. However, the result obtained from root biomass yield was partially disagreed with the finding reported by [2]. The variation of green root biomass yield might be due to doze of fertilizer application and boron, time of harvesting and seasonal variations.

Table 5. The Combined Mean agronomic data, yield and yield components over location over years.

Treatments	Root length (cm)	Shoot Length (cm)	ShootFBMY (t ha^{-1})	RootFBMY (t ha^{-1})	Total FBMY (t ha^{-1})	Root DBMY (t ha^{-1})	Shoot DBMY (t ha^{-1})	Tot DHrY (t ha^{-1})
Bricks	15.16c	51.37a	25.68b	50.85c	76.53c	11.139	3.47b	14.611
Kulumsa	19.2a	55.88a	41.88a	86.49a	128.37a	13.48	4.52a	17.996
Magnum	16.53b	45.387b	26.39b	55.18bc	81.57bc	12.385	3.51b	15.923
Robbos	17.81b	44.59b	27.50b	65.85b	93.35b	12.713	3.32b	16.028
Grand Mean	17.17	49.31	30.36	64.59	94.95	12.43	3.70	16.14
CV (%)	6.71	8.89	26.9	26.63	24.65	27.75	25.80	22.78
LSD(0.05)	0.65	2.09	1.95	5.85	6.99	NS	0.25	NS
Locations								
Sinana	16.15b	46.07b	31.16	53.89b	85.05b	10.84b	3.76	14.12b
Agarfa	17.92a	48.59a	29.57	75.30a	104.86a	14.52a	3.65	18.16a
LSD	1.73	2.41	Ns	4.14	4.94	0.82	Ns	0.9
Years								

Treatments	Root length (cm)	Shoot Length (cm)	ShootFBMY (t ha^{-1})	RootFBMY (t ha^{-1})	Total FBMY (t ha^{-1})	Root DBMY (t ha^{-1})	Shoot DBMY (t ha^{-1})	Tot DHrY (t ha^{-1})
2020/21	16.63b	47.76b	20.28c	39.39b	59.68c	8.98b	3.12b	12.12b
2021/22	15.78b	46.30b	23.62b	73.2a	96.82b	14.79a	3.31b	18.09a
2022/23	18.70a	52.31a	47.18a	81.18a	128.36a	13.52a	4.68a	18,2a
LSD	2.07	2.45	3.35	5.07	6.05	1.00	0.34	1.10

3.4. Dry Shoot Biomass Yield

The mean of analysis result indicated that dry shoot biomass yield was significantly different ($P < 0.05$) among the treatments. In (table 3), the highest shoot dry biomass yield (5.86 t ha^{-1}) was obtained from Kulumsa cultivar in 2022/23 at Agarfa sub site. The minimum shoot dry biomass yield obtained from the remaining three cultivars. The combined mean result within years and locations in (table 5); the maximum shoot dry biomass yield recorded in 2022/23 (4.68 t ha^{-1}). The minimum shoot was obtained in 2020/21 and 2021/21 years. However, locations was not significantly affected the dry shoot biomass yield. This result lined with the result obtained by [13].

3.5. Root Dry Biomass Yield

The combined analysis result of dry root biomass yield none significant different ($p > 0.05$) among the cultivars of fodder beet. The combined result of total dry herbage yield shown in table 5, ranges (11.14 -13.48 t ha^{-1}). However, locations and years affected root dry biomass yield. The maximum root dry biomass yield recorded at Agarfa sub site (14.52 t ha^{-1}) and the minimum obtained from Sinana on station (10.84 t ha^{-1}). Also a significant variation with a year, the maximum recorded in 2022/23 and 2021/22 (14.79 t ha^{-1} and 13.52 t ha^{-1}) respectively. The minimum root dry biomass yield recorded in 2020/21, the variation is might be due to rainfall condition and time of planting. This result line with the result reported by [13, 6].

3.6. Total Dry Herbage Yield of Fodder beet

The combined analysis result shown in table 5. Total herbage yield was not significantly different ($P > 0.05$) among the treatments. However, locations and years significantly affected fodder bee herbage yields. The highest total herbage yield (18.16 t ha^{-1}) was obtained at Agarfa location and the minimum recorded from Sinana location. Also year's significantly affected ($p < 0.05$). The maximum result of total dry herbage yield recorded in 2022/23 and 2021/22. The minimum obtained in 2020/21, might due to seasonal variation. This result agreed with the finding of [14] which reported dry herbage yield ranges from 7.11 to 15.00 t/ha.

4. Conclusion and Recommendation

The performance of fodder beet was carried out in the Highland Bale zone of Oromia regional state. The result showed that significant ($P < 0.05$) variation among the cultivars of fodder beet, which means the parameters of; Shoot fresh biomass yield, Root fresh biomass yield, shoot herbage yield, Root length, leaf length and survival rate. All tested fodder Beet cultivars well performed and adapted in the highland of Bale Zone. However Kulumsa cultivar was better in terms of their Biomass yield and other parameters and obtained some seed yields. Therefore it was concluded that Kulumsa cultivars promising to be demonstrated in the study area and under the same agro-climatic conditions and better to popularize for their livestock mix with poor quality (crop residues) as feed resources to enhance animal products.

Abbreviations

LSD: Least Significant Different
NS: None Significant
CV (%): Present of Coefficient Variations

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abdallah, E. F. and Yassen, A. A. (2008). Fodder beet productivity under fertilization treatments and water augmentation. Australian journal of Basic and Applied Sciences, 2(2): 282-287.

[2] Al-Jbawi, E., 2020. All about fodder beet (*beta vulgaris* subsp. crassa L.) as a source of forage in the world and Syria. Research Journal of Science–RJS1, pp. 24-44.

[3] AL-Jbawi, E. M., Bagdadi, M. and Nemr, Y., 2014. The effect of plant spacing on some quality traits of fodder beet (Beta Vulgaris var. crassa) varieties. International Journal of Environment. 3(3), 286-293.

[4] Ayele, S., Assegid, W., Jabbar, M. A., Ahmed, M. M. and Belachew, H., 2002. Livestock marketing in Ethiopia. A review of structure, performance and development initiatives. Socio-economics and Policy Research Working Paper 52. ILRI, Nairobi, Kenya.

[5] Chakwizira, E., Teixeira, E., Meenken, E., Michel, A. J. and Maley, S., 2018. Radiation use efficiency and biomass partitioning to storage roots in fodder beet crops. *European Journal of Agronomy*, *92*, pp. 63-71.

[6] Draycott, A. P. Christenson, D. R., 2003. Nutrients for sugar beet production: Soil-Plant relationships. CAB International, Wallingford, UK.

[7] El Sarage, E., 2013. Response of fodder beet cultivars to water stress and nitrogen fertilization in semi-arid regions. American Eurasian J. Agric. and Environ. Sci.,13(9), 1168-1175.

[8] Fleming, A., Dalley, D., Bryant, R. H., Edwards, G. and Gregorini, P., 2021. Fodder beet to support early and late lactation milk production from pasture, is it worth the risk. *Agricultural Systems*, 187, p. 102993.

[9] Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research, 2nd edition. John Viley and Sons Inc., New York.

[10] Ibrahim, Y. M. (2005). Ranges and forage (In Arabic). Dar Azza for Publication, Khartoum, Sudan, 300p.

[11] Limagrain, 2011. Fodder beet. Limagrain UK.

[12] Mulugeta Eshetu, Daniel Abegeja, Tilahun Chibsa, Negash Bedaso., 2022. Worm Collection and Characterization of Vermicompost produced using different worm species and waste feeds materials at Sinana on – Station of Bale highland southeastern Ethiopia. International Journal of Environmental & Agriculture Research (IJOEAR) ISSN:[2454-1850] [Vol-8, Issue-2, February- 2022]

[13] Muna E. Khogali, Yassin M. I. Dagash and Mahgoub G. EL-Hag, 2011. Productivity of fodder beet (Beta vulgaris var. Crassa) cultivars affected by nitrogen and plant spacing. *Agriculture and Biology Journal of North America* Issn Print: 2151-7517, ISSN Online: 2151-7525, https://doi.org/10.5251/abjna.2011.2.5.791.798

[14] Singh, D. and Garg, A. K., 2013. Evaluation of beet varieties for forage yield and quality parameters. Range Management and Agroforestry, 34(2), pp. 182-185.

[15] Tarawali, S. A., G. Tarawali, A. Lirbi and J. Hanson, 1995. Method for the evaluation of Forage legumes, Grasses and Fodder Trees for Feed Use as Livestock Feed. International Livestock Research Institute; Nairobi, Kenya.

[16] Wales, W. J. and Kolver, E. S., 2017. Challenges of feeding dairy cows in Australia and New Zealand. *Animal Production Science*, *57*(7), pp. 1366-1383.