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Fodder Beet (*Beta Vulgaris* L.) Yield and Quality Attributes as Affected by Sowing Date, Age at Harvest and Boron Application

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ABSTRACT

The forage potential of fodder beet (*Beta vulgaris* L.) grown under the Egyptian agricultural conditions has not been fully investigated. This study was carried out during two successive winter growing seasons (2014/2015 and 2015/2016) in Egypt and aimed to investigate the variations in yield and some quality attributes of fodder beet as affected by three sowing dates (15th September, 15th October and 15th November), three ages at harvest (120, 150, and 180 days after sowing - DAS), and boron application. Total, root, and shoot yields (t ha^{-1}), as well as root and shoot dry matter contents (g kg^{-1}) were evaluated. Fodder beet quality was judged in terms of the variations in the three fiber fractions (NDF, ADF, and ADL), in addition to the in vitro true digestibility (IVTD), and the NDF digestibility (NDFD). A pronounced response in most of the studied parameters to the different sowing dates and age at harvest was detected, while boron application had minimal influence on yield and quality of fodder beet. Early sowing (mid-Sept.) and late harvesting (180 DAS) resulted in the maximum fresh yield amounting to 170 ton ha^{-1}, while a delay in sowing to mid-Nov. resulted in 53% reduction in fresh yield. The maximum dry matter content, on the other hand, was achieved with late sowing (mid-Nov.) and late harvesting (180 DAS). The role of boron in nutrient translocation from shoots to roots was clear in the significant decrease of the shoot dry matter content. However, no effect was observed for the root and shoot fresh yields. Harvesting at 180 DAS lead to the accumulation of the highest significant amount from the three tested fiber fractions (NDF, ADF and ADL). Regarding digestibility, both IVTD and NDFD values, declined with the increase in plant age at harvest. Results of the current study indicated that the fiber fractions of fodder beet roots and shoots were distinguishably lower than other forage crops. Furthermore, the high digestibility of 79% for IVTD and 60%for NDFD for fodder beet roots and comparable values for shoots, emphasize the excellent fiber quality of this crop. Records of the quality attributes of fodder beet, in the current study, in addition to its high yield, suggest that it can complement the high-protein berseem clover feed in critical periods of forage shortage and improve the nutritional value of the produced feed in the winter season in Egypt.

Key words: Fodder beet, winter forages, productivity, fiber fractions, digestibility.

INTRODUCTION

Fodder beet is a member of the family Chenopodiaceae, a subspecies of *Beta vulgaris* L. It is believed that fodder beet resulted from crossing sugar beet with mangel, a kind of beet that was used for animal feeding in the eighteenth century (Claridge, 1972; Langer and Hill, 1982). By time, fodder beet gained increasing attention as an important component of dairy cattle winter feeding systems in many parts of the world (Niazi *et al.*, 2000). Fodder beet shoots and roots are palatable and easily digestible and liked by most livestock (Chatterjee and Das, 1989). The chemical composition of fodder beet varies between cultivars, growing conditions, and among shoots and roots of the plant (Magat and Goh, 1990). The roots have up to 60% sugars (mainly sucrose), low crude protein (approximately 10%) and neutral detergent fibre (approximately 12%) contents (Matthew *et al.,* 2011). The shoots make up approximately one third of the DM of the whole plant (Clark *et al.,* 1987), and are characterized by their high protein content, around 11.4 - 15.8% (Nadaf *et al.,* 1998). While the shoots and roots may be used to feed the animals, the main fodder is the tuberous roots (Ibrahim, 2005). Shoots however, are thought to cause digestive upsets and, therefore, are removed during the harvesting of the roots. This is mainly attributed to the oxalate levels in fodder beet shoots that bind the calcium during digestion forming insoluble calcium oxalate which is excreted with the feaces and can result in cows suffering milk fever-like symptoms. This problem can be safely overcome by allowing for a suitable transition on to the crop, this transition would greatly help the animals to tolerate the oxalate levels in the shoots. After about 14 days transition, the rumen effectively detoxifies the oxalate

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in the diet (Baker and Eden, 1954). The crop contains 10-15% dry matter and may yield up to 20 t ha^{-1} of dry matter in one harvest as compared to 13-15 t ha^{-1} from four cuts of grass (Kiely *et al.*, 1991). The nutritive value of fodder beet is equivalent to 9.69 tons of feed barely (Paska, 1994), and its calculated energy content was about 61% TDN (Total Digestible Nutrient) compared to 58% for Rhodes grass (Nadaf *et al.,* 1998). It is confirmed in previous studies that using fodder beet as an additional dietary component, normally increases metabolizable energy intake (Phipps *et al.*, 1995). Farris *et al.* (2003) reported that the inclusion of fodder beet in a grass silage-based ration for dairy cows (30:70 DM ratio) resulted in increases in both dry matter intake and estimated metabolizable energy intake across a wide range of concentrate feed levels (3.0-12.0 kg DM per cow d^{-1}). Moreover, according to feed evaluation systems that predict increased microbial efficiency with increasing carbohydrate fermentation rate (Russell *et al.,* 1992), the sucrose of fodder beet (on average 59% DM) probably enhances the microbial protein synthesis from feed protein (Gruber, 1994). This would result in maintaining the desirable balance between ruminally degraded proteins and fermentable carbohydrates in the diet and, thus, improving nitrogen utilization in animal husbandry (Eriksson *et al.,* 2004). Besides its positive contribution to livestock nutrition, fodder beet is characterized by several agronomic advantages. It provides an alternative to brassicas in cropping rotations (Matthew *et al.,* 2011), it is suitable for cultivation in saline-affected soils (Rammah *et al.*, 1984) and recently, recommended as a source of biomethane due to its high fresh matter yield and digestibility (Laufer *et al.,* 2016).

In fodder beet, recommended agronomic practices for maximizing productivity and quality are still under review. Sowing and harvesting dates are reported to have significant effects on the crop's yield and quality (Matthew *et al.,* 2011). In addition, amongst the dicot plant families, the *Beta* spp. are known for their high sensitivity to boron deficiency (Martens and Westermann 1991).

The current study aimed to investigate the effect of three sowing dates; namely, mid-September, mid-October and mid-November, and three ages at harvest; 120, 150 and 180 days after sowing (DAS) on yield and quality attributes of fodder beet grown with and without the application of boron. The studied parameters included total, root, and shoot yields (ton ha^{-1}), root and shoot dry matter contents (g kg^{-1}), and the following quality attributes: neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), in vitro true digestibility (IVTD), and neutral detergent fiber digestibility (NDFD) for both the root and shoot fractions (g kg^{-1}).

MATERIALS AND METHODS

Treatments and management:

Field experiments were carried out at the experimental station of the Faculty of Agriculture, Alexandria University in Alexandria, Egypt, during the winter seasons of 2014/2015 and 2015/2016. Soil of the experimental location was moderately alkaline (pH 8.4), sandy loam in texture, with 1.5% organic matter content and EC 1.30 dSm^{-1}.

A split-split-plot experimental design with three replicates was used to investigate the response of yield and some quality attributes of the fodder beet cultivar (Voroshenger) to three sowing dates (SD) – assigned to the main plots, three ages at harvest (AH), in the sub-plots and one boron (B) foliar application, in addition to the control treatment (sprayed with water) in the sub-sub-plots. The three investigated sowing dates were 15^{th} of each of the months of September, October and November, in both growing seasons (2014 and 2015). Experimental plots were harvested either after 120, 150 or 180 DAS for each sowing date, representing the three tested ages at harvest. Half of the experimental plots were sprayed with borax (11.3% Boron) at the rate of 1.2 kg ha^{-1}, one month before harvesting, while the other half was left without any borax application. The used boron application rate was equivalent to 141.25 ppm.

Seed beds were prepared by dividing each plot (9 m^2) into five ridges (60 cm apart and 3 m long), where three seeds were placed in hills, 25 cm apart, on the upper half of one side of each ridge. After two weeks from sowing, all the plots were thinned to one plant per hill. Phosphorous was added once with seed bed preparation at the rate of 100 kg P_2O_5 ha^{-1}, in the form of calcium mono phosphate (15.5% P_2O_5), while nitrogen in the form of ammonium nitrate (33.5%N) was applied at the rate of 40 and 80 kg N ha^{-1},two weeks and two months after sowing, respectively. Leaf worms were sprayed with 239 g Lannate (S-methyl-N-[(methylcarbamoyl)oxy]thioacetimidate) dissolved in 477 Liter water/ha twenty days after each sowing date and weeds were hoed when necessary.

At the time of harvesting, plants were pulled out of the soil, and fresh yield of each of roots and shoots per plot was determined. A representative sub sample of roots and shoots, each of approximately 1 kg from each plot was dried at 60^0C until constant weight was reached to determine the dry matter (DM) concentration in each component per plot.

Analytical procedures:

The chemical analyses of the different quality parameters were carried out at the laboratories of the Agronomy Department (Forage Group), College of Agriculture and life Sciences, North Carolina State University, USA.

The dried sub-samples of roots and shoots were uniformly ground to a particle size of 1-mm. The concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined sequentially using the semiautomatic ANKOM^{220} Fiber Analyzer (ANKOM Technology, Macedon, NY, USA) after Van Soest *et al.* (1991). NDF and ADF were analyzed with a heat stable amylase and expressed inclusive of residual ash, while ADL content was corrected after the residual ash content. Ash was determined by combusting the sub-sample in a muffle oven at 550^{0}C for 3h (AOAC, 2012). In vitro true digestibility (IVTD) and neutral detergent fiber digestibility (NDFD) for the samples were determined using the Ankom Daisy^{II} Incubator (ANKOM Technology, Macedon, NY, USA) after Goering and Van Soest (1970). High producing lactating cows were used as inoculum donors. Their diet was a typical Northeastern US total mixed ration (TMR) with the primary ingredients consisting of corn silage, haylage, brewers grains, high moisture shelled corn (HMSC), corn meal, protein mix, hay, and minerals. Ruminal fluid was collected before morning feeding from two fistulated cows, to ensure that the natural variation among animals was maintained and, at the same time, the effects of unusual rumen inocula or rumen environments were reduced. After collection, the ruminal fluid was placed into pre-warmed thermo-containers (39^{0}C) under anaerobic conditions and transported immediately to the laboratory. In the laboratory half the ruminal fluid was strained through cheesecloth to collect the liquid phase, the other half was blended then strained through cheesecloth to collect the solid phase, finally the two fractions were blended together, strained through cheesecloth and kept in water bath (39^{0}C) under continuous CO_2 purge until starting the inoculation. At the time of inoculation, dry, ground samples (0.25 g, 1mm particle size) were incubated in Van Soest buffer/ruminal fluid mixture for 48h under anaerobic conditions at 39^{0}C. After incubation, samples were extracted using NDF procedure to remove bacterial contamination. The residue is undigested fibrous material and used to determine IVTD (g kg^{-1} DM), and NDFD (g kg^{-1} NDF).

Statistical procedures:

The sowing dates, age at harvest, and boron application were tested for significance using Proc Mixed of SAS 9.4 (SAS Institute, Inc., 2012). Fresh yield and dry matter data from the 2014 and 2015 growing seasons were presented and discussed separately. The data of the fiber fractions (NDF, ADF, and ADL), IVTD and NDFD were presented in a combined analysis for the two growing seasons due to homogeneity of variance between the two experimental seasons (Winer, 1971).

Only replicates were considered random. The investigated response variables (V) then were analysed according to the following model:

$$V_{ijk} = \mu + R_l + SD_i + e_i + AH_j + (SD \times AH)_{ij} + s_{ij} + B_k + (SD \times B)_{ik} + (AH \times B)_{jk} + (SD \times AH \times B)_{ijk} + t_{ijk}$$

where μ is the overall mean, R_l is the replication (l = 1,2,3), SD_i is the sowing date effect (i = 1,2,3), AH_j is the age at harvest effect (j = 1,2,3), B_k is the boron effect (k = 1,2), $(SD \times AH)_{ij}$ is the effect of the interaction between the sowing date and age at harvest, $(SD \times B)_{ik}$ is the effect of the interaction between the sowing date and boron application, $(AH \times B)_{jk}$ is the effect of the interaction between age at harvest and boron application, e_i is the effect of main plot, and s_{ij} is the effect of sub-plot, and tijk is the effect of the sub-sub-plot.

Significance was declared at P<0.05, and means were compared with the least significant difference (L.S.D) procedure.

RESULTS AND DISCUSSION

Data of the yield and dry matter concentration, as well as the fiber fractions, IVTD, and NDFD will be presented and discussed. Main effects of the studied factors will be discussed when the interaction is not significant.

Fresh yield and dry matter concentration:

Analysis of variance presented in Table (1) revealed that the fodder beet total fresh yield (ton ha^{-1}), and its components (root and shoot) significantly varied among the three sowing dates in both seasons. Similar results were obtained for total fresh yield and root yield for the age at harvest in both seasons. Shoot yield however, showed insignificant variation for age at harvest in both seasons. Concerning the root and shoot DM concentrations (g kg^{-1}), both were significantly influenced by the age at harvest only in 2014. On the other hand, all yield attributes were not significantly affected by boron application in either growing season, but root and shoot DM were significantly affected by boron application in 2014 and 2015 growing seasons (Table 1). All two-way and three-way interactions among the three studied treatments showed insignificant variations for the measured traits (Table1).

Table 1. Mean squares and levels of significance of the total, root, and shoot yields (ton ha^{-1}), root and shoot dry matter concentrations (g kg^{-1}) of fodder beet as affected by the sowing dates (SD), age at harvest (AH), and boron application (B) and their interactions, in 2014 and 2015 growing seasons

Effect	D.F.	Total Yield	Root Yield	Shoot Yield	Root DM	Shoot DM
			Growing season 2014			
SD	2	38090.78*	10425.96*	9801.70*	5708.83^{ns}	632.75^{ns}
AH	2	22075.09**	20731.04**	975.32^{ns}	3677.02**	1378.96**
B	1	138.98^{ns}	135.50^{ns}	549.64^{ns}	750.40*	516.40*
SD x AH	4	1195.59^{ns}	404.10^{ns}	241.91^{ns}	288.45^{ns}	270.64^{ns}
SD x B	2	38.87^{ns}	149.51^{ns}	42.15^{ns}	12.73^{ns}	51.44^{ns}
AH x B	2	164.71^{ns}	104.33^{ns}	134.60^{ns}	156.85^{ns}	16.23^{ns}
SD x AH x B	4	586.46^{ns}	112.58^{ns}	414.47^{ns}	9.04^{ns}	6.90^{ns}
			Growing season 2015			
SD	2	34858.33*	9789.49**	9092.15**	198.44^{ns}	1392.45^{ns}
AH	2	21140.11**	18854.20**	799.94^{ns}	495.96^{ns}	249.31^{ns}
B	1	891.41^{ns}	35.77^{ns}	569.99^{ns}	628.26*	925.87*
SD x AH	4	632.34^{ns}	91.99^{ns}	466.77^{ns}	228.12^{ns}	60.30^{ns}
SD x B	2	146.49^{ns}	67.72^{ns}	84.35^{ns}	22.14^{ns}	75.43^{ns}
AH x B	2	47.01^{ns}	73.86^{ns}	6.07^{ns}	23.14^{ns}	45.53^{ns}
SD x AH x B	4	658.85^{ns}	398.81^{ns}	227.70^{ns}	47.82^{ns}	45.00^{ns}

*Significant at 0.05 level of probability - **Significant at 0.01 level of probability - ns: Non-significant

Main effects of the tested factors on the yield and DM concentration are presented in Table (2). Means of the total yield revealed that the fodder beet maximum fresh yield was achieved when sown in mid-Sept. (168.02 and 165.87 ton ha^{-1}) and mid-Oct. (169.94 and168.96 ton ha^{-1}) compared to the late sowing in mid-Nov. (89.32 and 91.24 ton ha-1), in both growing seasons, respectively. The same trend was observed for root and shoot yields in both seasons (Table 2). Recommendations of the Egyptian Ministry of Agriculture for growing fodder beet suggested that the crop could be grown from September to December, with October and November being the optimum dates. Results of the current study, showed that, under the conditions in Alexandria region, delaying the sowing date to mid-Nov. has led to a significant reduction of about 53% in total fresh yield, nearly 57% in root yield and 48% in shoot yield as an average for both seasons (Table 2). These results are in agreement with those of Al-Jbawi *et al.* (2015) in Syria, where late sowing (mid-January) significantly reduced root and shoot yields compared to autumn sowing (mid-October). In addition, in a study conducted in New Zealand, Martin and Drewitt (1984) reported significant effect for the sowing date on the productivity of fodder beet, where, September sown crop yielded about 20% more, and December sown crop about 50% less than October sown crop. The data of Martin (1986) on light interception through the various growth stages of sugar beet explains why the sowing date should have a greater influence on yield than harvesting date. While late harvesting extends the yield accumulation phase at a time when light levels are comparatively low, early sowing extends the yield accumulation phase at a time when light levels are comparatively high. In Egypt, the average recorded temperature in 2014 was 27, 23 and 20°C for September, October and November, respectively, and 28, 25 and 21°C for the three respective months in 2015. Thus, the decrease in temperature from September to November during the two growing seasons suggests that the yield reduction may be temperature-related rather than light-related.

As for the effect of the age at harvest, fodder beet fresh total and root yields harvested after 180 days gave significantly higher yields than those harvested after 150 days in both seasons. Early harvesting (120 DAS) resulted in the least significant fresh total and root yield in both seasons (Table 2). Shoot yield was insignificantly affected by the age at harvest indicating that the increase in total fresh yield was attributed to increase in root weight rather than shoot weight. Similarly, root and shoot DM were significantly higher at 180 DAS than at 120 DAS only in 2014. Although not significant, the same trend was observed for root DM in 2015 but not for shoot DM. These results are in agreement with the results reported by Martin (1983) for two fodder beet cultivars in New Zealand sown and harvested at varying dates, where delaying harvesting date led to an increase in root fresh weight. Results are also in general agreement with the investigations of

Albayrak and Yuksel (2010), in Turkey, where a significant increase in both root yield and root DM was observed with increasing age at harvest from 150 to 165, 185 and 195 DAS, respectively. Maximum amount of total fresh yield achieved in the current study was 171 ton ha-1, with the application of 120 kg N ha^{-1}. The production achieved in this study was similar to the findings of Khogali *et al.* (2011a) for the same cultivar in Sudan, where the maximum amount of total fresh yield (175 ton ha^{-1}) was recorded for 120 kg nitrogen ha^{-1}. On the other hand, the maximum amount of root fresh yield reported in the current study (119 ton ha^{-1}), was more than the 97 ton ha^{-1} reported by Albayrak and Yuksel (2010) even with 80 kg N ha^{-1} more than the 120 kg N ha^{-1} applied in this study. Regarding the high DM concentration of fodder beet roots as compared to that in the shoots in both seasons, similar findings were reported, for the same cultivar (Voroshenger), evaluated in Sudan by Khogali *et al.* (2011b) and in Oman by Nadaf *et al.* (1998).

The effect of the boron foliar application was insignificant for the total fresh yield, root and shoot yields, in both seasons. However, a general trend could be observed, where an increase in fresh total yield and its components was achieved with boron application. Moreover, the boron application significantly decreased the shoot DM, and at the same time increased the root DM compared to the control treatment (Table 2). The decrease in the shoot DM with the boron application reached 7.6% and 10%, in 2014 and 2015, respectively, while the increase in root DM content amounted to 6.3% and 5.9%, in 2014 and 2015, respectively. Boron is known to treat heart rot disease in beets (Belvins and Lukaszewski 1998), in addition to its role in photosynthesis and sugar metabolism and transport (Bonilla *et al.,* 1980). This clearly explains the effect boron played in translocating DM from the shoots to the roots observed in Table (2), but does not explain why there was no clear effect of boron on fresh weight translocation. Hussein *et al.* (2011) studied the effect of two boron concentrations (75 and 150 ppm) on some agronomic characteristics of fodder beet. They observed that higher shoot, root and total fresh and dry weights per plant were achieved with the lower concentration of boron (75 ppm) than the higher concentration (150 ppm). Based on these results a boron concentration of 141 ppm applied a month before harvest, in the current study, might not be the optimum dose to induce a significant increase in the root fresh weight. Rather a lower boron dose with prolonged application might have had a positive effect on shoot-root fresh weight translocation as observed in other root crops (Sarkar *et al.,* 2007).

Root and shoot fiber fractions and digestibility:

Analysis of variance of the root and shoot fiber fractions, combined over the two growing seasons and presented in table (3), highlighted a significant influence for the varying sowing dates and age at harvest on the three investigated fiber fractions (NDF, ADF, and ADL) for the roots and shoots. Nonetheless, the ADL content for both the root and the shoot was significantly affected by the two-way interaction between the sowing date and the age at harvest. The effect of the boron application on the other hand, was insignificant in case of the three parameters for the roots and shoots. It is clear from table (4) that the three fiber fractions followed the same trend in response to the varying sowing dates and age at harvest. Plants, harvested at 180 DAS, were characterized by the highest significant amounts of the root and shoot NDF, ADF, and ADL. The increase in the root fiber fraction from the earliest (120 DAS) to the latest (180 DAS) harvests reached 23.68, 22.20, and 45.55% for NDF, ADF, and ADL, respectively. While the increase in case of shoot fiber fractions amounted to 14.78, 12.27, and 19.46%, from the earliest to the latest harvests for the same fiber fractions, respectively. This trend is rather expected, since it is generally documented for most forage plant species that fiber content, especially the lignin fraction, usually increases with delayed harvest or with increase in plant age (Van Soest, 1994, Ball *et al.*, 2001).

Concerning the effect of sowing date on the three tested fiber fractions, the highest significant values for the fiber fractions, for both roots and shoots, were scored for the earliest sowing date (mid-Sept.). Although sowing date has been reported not to affect the fiber fraction contents in fodder beet (Chakwizira *et al.,* 2016), our results appear not to be in harmony with those reports. The effect of sowing date on the fiber fractions might be explained by the fact that forage beet sown in mid-Oct. experiences longer periods of warm weather compared to that sown later in the season. Forages produced in warmer temperatures tend to be of lower quality compared to those produced in cooler temperatures (Ball *et al*., 2001). Roots of fodder beet were observed to show less values for each of the NDF, ADF, and ADL fractions than shoots which is supported by the results of Chakwizira *et al.* (2013). Fodder beet generally (roots and shoots) comprises less amount of fibers (of any of the three fiber fractions) than other forage crops including forage cowpea, Sudan grass, and pearl millet (Salama and Zeid 2016). Also when compared to berseem clover of NDF= 389.23 g kg^{-1} and ADF= 217.58 g kg^{-1}, as reported by Salama and Badry (2015),

Table 2. Variations in the total, root, and shoot yields (ton ha^{-1}), and root and shoot dry matter concentrations (g kg^{-1}) as affected by the sowing dates, age at harvest and boron application in 2014 and 2015 growing seasons

Effect	Total yield		Root yield		Shoot yield		Root DM		Shoot DM	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Sowing date:										
Mid-Sept.	168.02 a*	165.87 a	93.21 ab	91.89 b	74.82 a	73.98 a	97.84	109.29	75.33	78.94
Mid-Oct.	169.94 a	168.96 a	105.62 a	106.13 a	64.32 a	62.83 a	111.50	115.66	74.61	67.98
Mid-Nov.	89.32 b	91.24 b	59.14 b	60.55 c	30.19 b	30.70 b	133.16 a	110.84	85.22	85.37
Age at harvest:										
120 DAS	103.33 b	103.53 b	51.05 c	52.15 c	52.28	51.37	99.46 b	106.85	71.00 b	81.68
150 DAS	153.02 a	153.34 a	88.09 b	89.84 b	64.94	63.50	115.05 a	111.62	76.11 b	75.90
180 DAS	170.93 a	169.20 a	118.83 a	116.57 a	52.10	52.63	128.00 a	117.33	88.06 a	74.72
Boron application:										
Control	140.82	137.96	84.40	85.37	53.25	52.59	110.44 b	108.52 b	81.48 a	81.57 a
Boron	144.03	146.09	87.57	87.00	59.63	59.08	117.90 a	115.34 a	75.30 b	73.29 b

* Means followed by different small letter(s) within the same column, for each year and studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability

Table 3. Mean squares and levels of significance of the root and shoot NDF, ADF, and ADL (g kg^{-1}) of fodder beet as affected by the sowing dates (SD), age at harvest (AH), and boron application (B) and their interactions, combined for the two growing seasons

Effect	D.F.	Root			Shoot		
		NDF	ADF	ADL	NDF	ADF	ADL
SD	2	7708.25**	3558.05*	663.16**	9207.42*	3732.99**	166.09**
AH	2	20189.51**	4463.67**	1504.96**	14223.57**	2568.88*	221.13**
B	1	447.26^{ns}	388.55^{ns}	0.38^{ns}	1713.21^{ns}	793.96^{ns}	5.42^{ns}
SD x AH	4	1753.56^{ns}	657.90^{ns}	32.08**	904.19^{ns}	144.68^{ns}	12.39**
SD x B	2	411.86^{ns}	130.35^{ns}	4.89^{ns}	673.77^{ns}	89.57^{ns}	4.41^{ns}
AH x B	2	1425.38^{ns}	380.82^{ns}	14.15^{ns}	459.51^{ns}	395.12^{ns}	2.21^{ns}
SD x AH x B	4	170.08^{ns}	28.61^{ns}	14.52^{ns}	868.82^{ns}	522.71^{ns}	1.20^{ns}

*Significant at 0.05 level of probability - **Significant at 0.01 level of probability - ns: Non-significant

Table 4. Variations in the root and shoot NDF and ADF and ADL contents (g kg^{-1}) as affected by the sowing dates, age at harvest and boron application combined for both growing seasons

Effect	Root			Shoot		
	NDF	ADF	ADL	NDF	ADF	ADL
Sowing date:						
Mid-Sept.	259.13 a*	132.77 a	30.50 a	363.60 a	182.14 a	34.74 a
Mid-Oct.	236.30 ab	115.25 b	29.38 b	340.12 b	166.41 b	33.26 a
Mid-Nov.	218.02 b	104.97 b	19.47 c	318.37 c	153.38 c	28.90 b
Age at harvest:						
120 DAS	209.87 b	105.35 b	20.11 c	316.69 b	158.76 b	28.48 c
150 DAS	228.79 b	112.25 b	22.30 b	333.78 b	162.21 b	33.07 b
180 DAS	274.97 a	135.41 a	36.93 a	371.62 a	180.96 a	35.36 a
Boron application:						
Control	240.75	120.35	26.53	346.33	171.14	32.62
Boron	234.99	114.98	26.36	335.06	163.48	31.98

* Means followed by different small letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability

fodder beet had lower contents of the two respective fiber fractions, amounting to 237.82 and 117.66 g kg^{-1} as reported in the current study.

For the two-way interaction between the sowing dates and age at harvest (Table 5), it was observed that at each sowing date, the late harvesting resulted in the highest significant lignin content in the roots and shoots. The lignin content of the roots harvested at 180 DAS reached 41.68, 40.70, and 28.42 (g kg^{-1}) when sown on mid-Sept., mid-Oct., and mid-Nov., respectively. While the shoot ADL content reached 35.88, 36.67, and 33.53 (g kg^{-1}) for the three respective sowing dates. Moreover, comparing the three sowing dates at each age at harvest highlighted a decrease in the lignin content towards the late sowing (mid-Nov.).

Although the direction of the effects was consistent for root and shoot ADL, remarkable shifts in the magnitude of the variation were observed, which contributed to the significant interaction. The increase in the root ADL content towards the late harvesting amounted to 38.36, 43.83, and 58.52% for the three respective sowing dates. A less percentages of increase were observed in case of shoot ADL, amounting to 18.81, 15.11, and 24.93% for the three sowing dates. Analysis of variance of the digestibility measures (IVTD and NDFD) for fodder beet roots and shoots revealed a significant three way interaction among sowing dates, age at harvest and boron applications (Table 6). Means of the root and shoot IVTD (g kg^{-1} DM) presented in table (7) were highly variable as affected by the interaction. Results indicated that the highest significant root and shoot IVTD were achieved when plants were sown in mid-Nov., harvested 120 DAS with or without boron application. Generally, the difference between the highest (840 g kg^{-1}) and the lowest (760 g kg^{-1}) root IVTD values among all treatments was 9.5%. Concerning the shoot IVTD, the difference between the highest (810 g kg^{-1}) and the lowest (693 g kg^{-1}) values was 14.4%. The inconsistent direction of response as well as the highly variable magnitude of response might have greatly contributed to the significant three-way interaction. In case of the NDFD (g kg^{-1} NDF), means presented in table (8) suggested that young harvested plants at the age of 120 DAS that were grown in mid-October and without boron application resulted in the highest significant root and shoot NDFD. When searching for the set of treatments to achieve a compromise on the best IVTD and NDFD values for both roots and shoots, it appeared that growing in mid-November and harvesting at 120 DAS without boron application would be the best choice. Digestibility of NDF is one important parameter of forage quality. Oba and Allen (1999) studied the effects of the digestibility of neutral detergent fiber (NDF) of forages on performance of dairy cows and concluded that one-unit increase in NDF digestibility in vitro was associated with a 0.17-kg increase in DMI and a 0.25-kg increase in 4% fat-corrected milk.

Comparing the digestibility values of fodder beet shoots and roots at any sowing date or harvesting age revealed that it had excellent fiber digestibility values even to the standard digestibility value of 800 g kg^{-1} reported by Albrecht et al. (1987) for alfalfa leaves.

Results from tables 4 and 8 indicated that plants harvested at 180 DAS were characterized by higher content of NDF than earlier harvested plants. At the same time the NDFD values for those plants significantly declined with advancement in age, *i.e.*, NDF content was inversely proportional to its digestibility (NDFD %NDF). Similar findings were reported by Hoffman *et al.* (2003) for different forage grasses and legumes.

Caution should be taken when feeding animals on fodder beet alone, as a combination of low crude protein and low fiber with high soluble sugar concentrations, characterizing the crop, may reduce rumen pH and put animals at risk of rumen acidosis (Nichol *et al.*, 2003). Despite fodder beet being a good source of energy for livestock and offers good quality silage (Eriksson *et al.*, 2004), a diet consisting of only fodder beet would be suboptimal if fed without supplementation (Chakwizira *et al.,* 2013). It is, thus, recommended to feed fodder beet mixed with concentrates (Mousa, 2011), or other forage grasses (Kaur *et al.*, 2016). In Egypt, fodder beet occupies only 30 ha, and is by all means no rival to berseem clover dominating 1.2 million ha of the agricultural land (Muhammad *et al.*, 2014). However, fodder beet should be observed as a complement to berseem clover in many ways. Fodder beet proved to be highly tolerant to both drought and salinity stresses, much higher in water use efficiency and produces 106% more fresh forage yield than berseem clover (Mohamed *et al.,* 2013). Therefore, the crop is proposed as a winter forage in marginal areas (Abdallah and Yassen, 2008; Mohamed *et al.*, 2013; El-Sarag 2013), or complementing berseem clover in critical periods of forage shortage such as early summer season (Abd El-Naby *et al.,* 2014). Field trials carried out across the country, growing fodder beet on the boarders of the areas planted with berseem clover, revealed that an average production of 15.5 ton ha^{-1} of fodder beet could be achieved with minimal production costs and without any competition with the grown berseem clover (Bendary, 2009). This farming technique would provide the livestock production sector, in Egypt, with a substantial amount of high quality dry matter. Nutritionally, fodder beet is of high content of easily fermentable sugars that makes it a good source of energy for livestock, and together with berseem clover (as a source of protein), they would supply animals with a more carbohydrate-protein balanced feed. The crop has not yet been adopted by Egyptian farmers due to lack of knowledge of the importance of balancing the high protein diet provided from berseem clover with the carbohydrates content of fodder beet to reduce and manage the excess of protein being wasted and improve animal nutrition.

Table 5. Variations in root and shoot ADL content (g kg^{-1}) as affected by the interaction between the sowing date and age at harvest, combined for both growing seasons

Age at harvest	Root ADL			Shoot ADL		
	Sowing date					
	Mid-Sept.	Mid-Oct.	Mid-Nov.	Mid-Sept.	Mid-Oct.	Mid-Nov.
120 DAS	25.69 aB*	22.86 bC	11.79 cC	29.13 aB	31.13 aB	25.17 bC
150 DAS	24.12 aC	24.58 aB	18.20 bB	34.77 aA	36.43 aA	27.99 bB
180 DAS	41.68 aA	40.70 aA	28.42 bA	35.88 aA	36.67 aA	33.53 aA

* Means followed by different small letter(s) within the same row, and different capital letters within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

Table 6. Mean squares and levels of significance of the total, root, and shoot IVTD (g kg^{-1} DM), and NDFD (g kg^{-1} NDF) of fodder beet as affected by the sowing dates (SD), age at harvest (AH), and boron application (B) and their interactions, combined for the two growing seasons

Effect	D.F.	Root IVTD	Root NDFD	Shoot IVTD	Shoot NDFD
SD	2	37.35**	213.41**	33.72**	96.22**
AH	2	27.19**	954.30**	229.56**	226.39**
B	1	5.35*	0.17ns	1.19ns	0.07ns
SD x AH	4	14.77**	50.46**	6.94ns	24.53**
SD x B	2	14.32**	9.56**	1.69*	14.74**
AH x B	2	3.85*	110.22**	3.85*	6.35*
SD x AH x B	4	4.10*	7.28**	2.69*	6.44**

*Significant at 0.05 level of probability - **Significant at 0.01 level of probability - ns: Non-significant

Table 7. Variations in root and shoot IVTD (g kg^{-1} DM) as affected by the interaction between the sowing date, age at harvest, and boron application, combined for both growing seasons

Sowing date	Root IVTD						Shoot IVTD					
	Age at harvest											
	120 DAS		150 DAS		180 DAS		120 DAS		150 DAS		180 DAS	
	Control	Boron	Control	Boron	Control	Boron	Control	Boron	Control	Boron	Control	Boron
Mid-Sept.	790	810	770	800	770	790	780	780	780	780	700	730
Mid-Oct.	810	810	780	820	773	760	770	760	780	770	693	710
Mid-Nov.	830	820	830	840	820	810	800	810	780	777	743	737
L.S.D.$_{0.05}$	18.7						17.0					

Table 8.Variations in root and shoot NDFD (g kg^{-1} NDF) as affected by the interaction between the sowing date, age at harvest, and boron application, combined for both growing seasons

Sowing date	Root NDFD						Shoot NDFD					
	Age at harvest											
	120 DAS		150 DAS		180 DAS		120 DAS		150 DAS		180 DAS	
	Control	Boron	Control	Boron	Control	Boron	Control	Boron	Control	Boron	Control	Boron
Mid-Sept.	720	690	590	640	570	600	630	640	610	610	500	550
Mid-Oct.	770	690	600	660	520	530	650	643	640	630	610	600
Mid-Nov.	760	720	690	710	637	627	610	623	603	570	570	550
L.S.D.$_{0.05}$	30.2						17.7					

CONCLUSION

Production of fodder beet total fresh yield amounted to 170 ton ha^{-1}. In general, early sowing (mid-Sept.) accompanied with late harvesting (180 DAS), gave the crop the chance to produce highest fresh total, shoot and root yields. Delayed sowing (mid-Nov.) caused a 53% reduction in fresh yield compared to early sawing. Boron foliar application had minimal effects on the studied parameters. However, a more recognizable response could be expected if boron application is split into several doses throughout the growing season. Content from the different fiber fractions increased with extended age at harvest. As the crop matured, the fiber fractions increased and fiber digestibility declined. Despite the observed decline in digestibility, fodder beet showed high levels of fiber digestibility of 79% for IVTD and 60% for NDFD of roots and 73% for IVTD and 55% for NDFD of shoots for the early sown and late harvested plants accompanied with maximum yield. These values are quite satisfactory for quality of any forage crop. It is thus recommended to encourage farmers to grow fodder beet in marginal areas, not competing with berseem clover, to complement berseem clover in critical periods of forage shortage, and improve the nutritional value of the produced feed.

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REFERENCES

Abdallah, E. F., and A.A. Yassen 2008. Fodder beet productivity under fertilization treatments and water augmentation. Aust. J. Basic and Appl. Sci. 2:282–287.

Abd El-Naby, Z.M., W.M. Wafaa, M.S. Amany, M. Shereen, and M.F. Abdel-Ghawad 2014. Evaluation of seven fodder beet genotypes under different Egyptian ecological conditions using regression, cluster models and variance measures of stability. Int. J. Curr. Microbiol. Appl. Sci. 3:1086-1102.

Albayrak, S., and O. Yuksel 2010. Effects of nitrogen fertilization and harvest time on root yield and quality of fodder beet (*Beta vulgaris var. crassa* Mansf.). Turk. J. Field Crops 15:59-64.

Albrecht, K.A., W,F. Wedin, and D.R. Buxton 1987. Cell-wall composition and digestibility of alfalfa stems and leaves. Crop Sci. 27:735-741.

Al-Jbawi, E., M. Bagdadi and, Y. Nemr 2015. The productivity of four fodder beet cultivars (*Beta Vulgaris* Var. Crassa) as affected by autumn and winter sowing. Int. J. Environ. 4:121-129.

AOAC International 2012 Official Methods of Analysis (19th Ed.) Association of Official Analytical Chemists. Gaithersburg, MD, USA.

Baker, C.J.L., and A. Eden (1954). Studies on the oxalate contents of the leaves of certain varieties of Beta vulgaris. J. Agr. Sci. 44:394-399.

Ball, D. M., M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, and M.W. Wolf 2001. Understanding forage quality. American Farm Bureau Federation Publication 1(01).

Bendary, M.M. 2009. Maximizing the benefit from berseem clover crop. APRI Site, ARS (In Arabic). http://www.apri-arc.net/posts/99377.

Blevins, D. G., and K.M. Lukaszewski 1998. Boron in plant structure and function. Annu. Rev. Plant Biol. 49:481-500.

Bonilla, I., C. Cadahia, O. Carpena, and V. Hernando 1980. Effects of boron on nitrogen metabolism and sugar levels of sugar beet. Plant and Soil 57: 3-9.

Chakwizira, E., E.D. Meenken, S. Maley, M. George, R. Hubber, J. Morton, and A. Stafford 2013. Effects of potassium, sodium and chloride fertilizer rates on fodder beet yield and quality in Canterbury. Proceedings of the New Zealand Grassland Association 75:261-270.

Chakwizira, E., J.M. de Ruiter, B. Malcolm, and S. Maley 2016. Winter growth and quality of fodder beet. A Plant & Food Research report prepared for: Seed Force. SPTS No. 12866. https://www.dairynz.co.nz/media/4298994/Winter_growth_and_quality_of_fodder_FINAL_WEB.pdf

Chatterjee, B.N., and P.K. Das 1989. Forage Crop Production: Principles and Practices. Oxford and IBH Pub. Co. Pvt. Ltd., New Delhi, Pp: 450. [*c.f.* Nadaf, S.K. *et al.*, 1998].

Claridge, J.H., and J.W. Hatfield 1972. Arable farm crops of New Zealand. Department of Scientific and Industrial research in association with A.H. and A.W. Reed, Wellington. Pp: 345.

Clark, P., D.I. Givens, and J.M. Brunnen 1987. The chemical composition, digestibility and energy value of fodder beet roots. Anim. Feed Sci. Technol. 18:225-231.

El-Sarag, E.I. 2013. Response of fodder beet cultivars to water stress and nitrogen fertilization in semi-arid regions. Am-Eurasian J. Agric. Environ. Sci. 13:1168-1175.

Eriksson, T., M. Murphy, P. Ciszuk, and E. Burstedt 2004. Nitrogen balance, microbial protein production, and milk production in dairy cows fed fodder beets and potatoes, or barley. J. Dairy Sc. 87:1057-1070.

Ferris, C.P., D.C. Patterson, F.J. Gordon, and D.J. Kilpatrick 2003. The effect of concentrate feed level on the response of lactating dairy cows to a constant proportion of fodder beet inclusion in a grass silage-based diet. Grass Forage Sci. 58:17-27.

Goering, H.K., and P.J. Van Soest 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). USDA Agriculture Handbook No. 379, Superintendent of documents, US Government Printing Office, Washington, D.C. 20402. Pp: 13-14.

Gruber, L. 1994. Verwertung von futterrüben und rübenmischsilagen bei milchkühen. Übers. Tierernähr. 22:243–280.

Hoffman, P.C., K.M. Lundberg, L.M. Bauman, and R.D. Shaver 2003. The effect of maturity on NDF digestibility. Focus on Forage 5(15).

Hussein, M.M., M.M. Shaaban, A.M. El-Saady, and A.A. El-Sayed 2011. Growth and photosynthetic pigments of fodder beet plants as affected by water regime and boron foliar fertilization. Nature and Science 9:72-79.

Ibrahim, Y.M. 2005. Ranges and forage. In Arabic. Dar Azza for Publication, Khartoum, Sudan, Pp:300.

Kaur, K., U.G. Phutela, and M. Goyal. 2016. Comparative analysis of fodder beet and Napier grass PBN233 as a better substrate for biogas production. Indian J. Sci. Technol. 9:1-4.

Khogali, M.E., Y.M.I. Dagash, and M.G. El-Hag 2011a. Productivity of fodder beet (*Beta vulgaris* var. *Crassa*) cultivars affected by nitrogen and plant spacing. Agric. Biol. J. North America 2:791-798.

Khogali, M.E., Y.M.I. Dagash, and M.G. El-Hag 2011b. Nitrogen fertilizers effects on quality of fodder beet (*Beta vulgaris* var. *Crassa*). Agric. Biol. J. North America 2:270-278.

Kiely, P.O., A.P. Moloney and J. Meagher 1991. Ensiling and feeding whole-crop fodder beet. Landbau Forchung-voelkerode Sonderheft 123:269-272.

Langer, R.H.M, and G.D. Hill 1982. Agricultural plants. Cambridge University Press, Cambridge. Pp: 344.

Laufer, D., O. Nielsen, P. Wilting, H.J. Koch, and B. Märländer 2016. Yield and nitrogen use efficiency of fodder and sugar beet (*Beta vulgaris* L.) in contrasting environments of Northwestern Europe. Eur. J. Agron. 73:124-132.

Magat, S.S., and K.M. Goh 1990 . Effects of chloride fertilizers on ionic composition cation anion balance and ratio of Fodder beet (*Beta vulgaris* L.) grown under field conditions. New Zeal. J. Agr. Res. 33:29-40.

Martens, D.C., and D.T. Westermann 1991. Fertilizer applications for correcting micronutrient deficiencies. In: Micronutrients in Agriculture [Mortvedt, J.J., Cox, F.R., Shuman, L.M., Welch, R.M. (eds)] SSSA Book Series No. 4. Madison, WI. Pp: 549–592.

Martin, R.J. 1983. Effect of cultivar, sowing date and harvest date on yields and sugar contents of beet on a dry land site in Canterbury. New Zeal. J. Exp. Agr.11:191-197.

Martin, R.J. 1986. Radiation interception and growth of sugar beet at different sowing dates in Canterbury. New Zeal. J. Agr. Res. 29:381-390.

Martin, R.J., and E.G. Drewiitt 1984. Effect of sowing date and harvest date on yields of irrigated sugar beet and fodder beet on 2 soil types in Canterbury. New Zeal. J. Exp. Agr. 12:185-195.

Matthew, C., N.J. Nelson, D. Ferguson, and Y. Xie 2011. Fodder beet revisited. Agron. New Zeal. 41:39-48.

Mohamed, M.M., M.A. El-Nahrawy, M.A. Abdu, and S.A. Shams 2013. Development of fodder resources in Sinai: The role of forage crops in agriculture development, North Sinai-Gevernorate, Egypt. J. Agron. 12:29-37.

Mousa, M.R.M. 2011. Effect of partial replacement of dietary concentrate feed mixture by fodder beet roots on productive performance of ewes and doe goats under the conditions of north Sinai. Asian J. Anim. Sci. 5:228-242.

Muhammad, D., B. Misri, M. El-Nahrawy, S. Khan, and A. Serkan 2014. Egyptian Clover (*Trifolium alexandrinum* L.) King of Forage Crops. FAO. www.fao.org/3/a-i3500e.pdf.

Nadaf, S.K., Y.M. Ibrahim, M. Akhtar, M.G. El Hag, and A.H. Al-Lawati 1998. Performance of fodder beet in Oman. Annals of Arid Zone 37: 377-382.

Niazi, B.H., J. Rozema, R.A. Broekman, and M. Salim 2000. Dynamics of growth and water relations of fodder beet and sea beet in response to salinity. J. Agron. Crop Sci. 184: 101-109.

Nichol, W., C. Westwood, A.J. Dumbleton, J. Amyes 2003. *Brassica* wintering for dairy cows: overcoming the challenges. Proceedings of the South Island Dairy Event. Pp: 154-172.

Oba, M., and M.S. Allen 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Paska, L. 1994. Selected aspects of management of Fodder beet production systems in the Slovac republic. Polnohospodarstvo (slovakia) 41:178-190.

Phipps R.H., J.D. Sutton, and B.A. Jones 1995. Forage mixtures for dairy cows: the effect on dry-matter intake and milk production of incorporating either fermented or urea-treated whole-crop wheat, brewers' grains, fodder beet or maize silage into diets based on grass silage. Anim. Sci. 61:491–496.

Rammah, A.M., F.M. Ali, and M.T. Hassan 1984. Evaluation of fodder beet cultivars for different locations and years. EMCIP Publication 1:215.

Russell, J. B., J. D. O'Connor, D. G. Fox, P. J. Van Soest, and C.J. Sniffen. 1992. A net carbohydrate and protein system for evaluating cattle diets. 1. Ruminal fermentation. J. Anim. Sci. 70:3551–3561.

Salama, H.S.A., and H.H. Badry 2015. Influence of variable mixing rates and nitrogen fertilization levels on the fodder quality of Egyptian clover (*Trifolium alexandrinum* L.) and annual ryegrass (*Lolium multiflorum* Lam.). Afr. J. Agric. Res. 10:4858-4864.

Salama, H.S.A., and M.M.K. Zeid 2016. Hay quality evaluation of summer grass and legume forage monocultures and mixtures grown under irrigated conditions. Aust. J. Crop Sci. 10:1543-1550.

Sarkar, D., B. Mandel, and M.C. Kundu 2007. Increasing efficiency of boron fertilizers by rescheduling the time and method of application for crops in India. Plant Soil 301:77-85.

SAS Institute Inc. 2012. SAS/STAT® 13.2 User's Guide. Cary, NC: SAS Institute Inc.

Van Soest, P. J. 1994. Nutritional ecology of the ruminant. Cornell University Press.

Van Soest, P.J., J.B. Robertson, and B.A. Lewis 1991 Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.

Winer, B.J. 1971. Statistical principles in experimental design. 2nd Edition. McGraw-Hill Kogakusha, LTD.

الملخص العربي

دراسات على إنتاجية وجودة بنجر العلف (*Beta vulgaris* L.) تحت تأثير مواعيد الزراعة والعمر عند الحصاد وإضافة عنصر البورون

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تم اجراء هذة التجربه خلال الموسم الشتوى لعامى ٢٠١٤ و٢٠١٥ بمحطة البحوث الزراعية بأبيس، التابعة لكلية الزراعة، جامعة الاسكندرية. الهدف من البحث كان دراسة التباين فى المحصول وبعض صفات الجودة لبنجر العلاف المنزرع تحت تأثير ثلاثة مواعيد زراعة وهم: ١٥ سبتمبرو ١٥ اكتوبر و١٥ نوفمبر، وثلاث أعمار للنبات عند الحصاد (١٢٠ و١٥٠ و١٨٠ يوم بعد الزراعة) وكذلك تأثير رش عنصر البورون. تم تقييم المحصول الكلى، محصول الجذور والعرش (طن/هكتار) هذا بالإضافة إلى محتوى الجذور والأوراق من المادة الجافة. تم كذلك تقييم جودة بنجر العلف من خلال دراسة أقسام الألياف المختلفة وهى الألياف المقاومة للتحلل فى المحلول المتعادل (NDF)، الألياف المقاومة للتحلل فى المحلول الحمضى (ADF) و مادة اللجنين (ADL) وكذلك عن طريق الهضم الحقيقى المعملى In vitro true digestibility (IVTD g kg^{-1} DM)، وهضم الألياف المقاومة للتحلل فى المحلول المتعادل NDF digestibility (NDFD g kg^{-1} NDF). أظهرت النتائج تأثر أغلب الصفات المدروسة تأثراً واضحاً بمواعيد الزراعة وعمر النبات عند الحصاد، بينما كان لإضافة البورون تأثير طفيف على محصول وجودة بنجر العلف. أدى التبكير فى ميعاد الزراعة (نصف سبتمبر) مع التأخير فى الحصاد (١٨٠ يوم بعد الزراعة) إلى إنتاج أعلى كمية محصول لوحدة المساحة (١٧٠ طن/هكتار). بينما أدى تاخير ميعاد الزراعة (نصف نوفمبر) إلى إنخفاض المحصول بنسبة ٥٣%. تم الحصول على اعلى محتوى من المادة الجافة عند ميعادى الزراعة والحصاد المتأخرين. لعب عنصر البورون دوراً واضحاً فى إنتقال العناصر الغذائية من المجموع الخضرى للجذور، ظهر فى إنخفاض معنوى فى محتوى الاوراق من المادة الجافة ولكن لم يلاحظ أى تاثير معنوى على محصول العرش والجذور. أدى الحصاد عند ١٨٠ يوم بعد الزراعة إلى تراكم أكبر كمية من أقسام الألياف المختلفة مما إنعكس بالسلب على كل من ال IVTD وNDFD اللذان إنخفضا مع التقدم فى عمر النبات عند الحصاد. أظهرت نتائج الدراسة أيضاً أن محتوى جذور وعرش بنجر العلف من الأليـاف كانت منخفضة مقارنة بمحاصيل الأعلاف الأخرى. بالإضافة الى ذلك، أكدت قيم الهضم المرتفعة لجذور بنجر العلف (٧٩% IVTD ٦٠% NDFD) وعرشه على الجودة المرتفعة للمحصول.

النتائج المتحصل عليها لصفات الجودة المدروسه لبنجر العلاف بالإضافة الى محصوله المرتفع ترجح إمكانية إستخدامه لتعويض العجز فى إنتاجية محاصيل العلف وكذلك لتحسين القيمه الغذائية لمحاصيل العلف الغنية بالبروتين مثل البرسيم المصرى خلال الموسم الشتوى فى مصر.