Journal of Agricultural Science; Vol. 12, No. 8; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Yield and Composition of Buckwheat Biomass Relative to Forage Use

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Received: May 9, 2020 Accepted: June 11, 2020 Online Published: July 15, 2020

doi:10.5539/jas.v12n8p129 URL: https://doi.org/10.5539/jas.v12n8p129

The research was financed by Virginia Agricultural Council, and Virginia State University and US Department of Agriculture (NIFA/Evans-Allen Program).

This paper was contribution of Virginia State University, Agricultural Research Station. Use of any trade names or vendors does not imply approval to the exclusion of other products or vendors that may also be suitable.

Abstract

Buckwheat (*Fagopyrum esculentum* Moench), a pseudo-cereal, has potential as a forage crop, cover crop, grain crop for animal feed and human food, honey bee crop, and a smother crop for weed suppression. Even though, buckwheat has a long history in Virginia, currently this crop is almost non-existent in this area. The New Crops Program of Virginia State University started researching buckwheat in 2015 as an alternate food crop and as a plant to support honey bees. These studies led into evaluation of buckwheat as a forage crop. Approximately 30-day old buckwheat tissue of two cultivars (Koto and Mancan), planted on June 22 or July 20 during 2015, yielded 4784 pounds fresh weight and 1000 pounds dry matter per acre. Buckwheat biomass contained approximately 21 percent protein and approximately 6 percent oil. Quality of buckwheat forage compared well with literature values for alfalfa hay, perennial peanut, soybean, white lupin, and Tepary bean forage.

Keywords: *Fagopyrum esculentum*, forages, protein concentration, oil concentration, ADF, NDF, minerals, alternate crops

1. Introduction

Buckwheat (*Fagopyrum esculentum* Moench, Family Polygonaceae) is considered a pseudo-cereal. Buckwheat has a reputation for growing on poor soils and thriving in a wide variety of soils. Even small amounts of fertilizer are known to considerably enhance buckwheat performance in low fertility soils. Buckwheat can be used as a forage crop, cover crop, grain crop for animal feed and human food, honey bee crop, and a smother crop for weed suppression. Buckwheat is an extremely short-duration crop and has great potential when "normal" crops fail. It improves the soil and suppresses weeds; needs very little attention during the growing season; makes a great rotation crop; often grows well on low-fertility land; is a high-yield crop; and can be planted as late as mid-July in many areas and is fast growing—70 days from planting to harvest full. Fertilizer needs of buckwheat are limited, producing savings in labor, fuel and chemical inputs.

Buckwheat has been grown in Virginia since late 1700s (Thomas Jefferson's letter to George Washington dated May 14, 1794 indicated his interest in buckwheat as a rotation crop https://founders.archives.gov/documents/washington/05-16-02-0055). However, today the crop is almost non-existent in Virginia. Even though, literature indicates that buckwheat can be used as a forage (Cheng, 2018; Amelchanka et al., 2010; Mariotti et al., 2016; Mu et al., 2019), information about use of buckwheat as a summer forage crop in Virginia and adjoining states is non-existent. Objectives of the current study were to determine buckwheat forage yield following different planting dates and to characterize its' nutritional value for forage use.

2. Materials and Methods

2.1 Plant Material

The plant material for this study consisted of two buckwheat cultivars: black-hulled Koto and brown-hulled Mancan. Koto buckwheat became available to growers in the Northeast United States for the first time in 2002. It was developed in a joint project between Cornell University and Kade Research, and funded by Birkett Mills.

Koto was in commercial trials in New York annually from 1999 through 2001. It has out yielded Manisoba by 13% on average and is more stress tolerant (http://www.hort.cornell.edu/bjorkman/lab/buck/guide/varieties.php). Mancan buckwheat was developed by Agriculture and Agri-Food Canada in Morden, Manitoba (Izydorczyk et al., 2014).

2.2 Production and Sampling

An experiment with Mancan and Koto buckwheat varieties was planted three times during 2015 in the field [Abel sandy loam-Fine Loamy mixed thermic Aquatic Hapridult soil with 6.5 pH, 1.5% organic matter, and P, K, Mg, and Ca concentrations (mg/kg) 77, 54, 68, and 395, respectively] at Randolph Farm of Virginia State University in Ettrick, Virginia (USA). The planting dates were June 22, July 20, and August14. These plots didn't receive any fertilizer or irrigation. The field design was a RCBD with four replications. Each plot consisted of four rows (37.5 cm apart) with approximately 100 seeds planted in 2.5 m row length. One sample (approximately 40 cm row length from the one of the middle rows) was harvested from each plot for data collection. Samples of biomass were collected about 30 days after planting.

2.3 Data Collection

Fresh and dry matter were recorded in grams and then converted to kg/ha for all plots. Concentrations of N, sugars (Sucrose, fructose, glucose, raffinose, stachyose, and verbascose), oil, ADF, NDF, B, P, K, Ca, Cu, Fe, Mg, Mn, Na, S, and Zn were determined, only for first and second plantings, using AOAC methods (AOAC, 2016) and by using established commercial equipment by Waypoint Analytical Laboratory (Richmond, Virginia, USA). Total protein concentration was calculated by multiplying N content with protein factor 6.25.

Oil and sugar concentrations were determined in the Common Laboratory of Agricultural Research Station of Virginia State University. The oil was extracted from ground buckwheat dry material (5 g) three times at room temperature by homogenization for 2 min in 20 mL hexane/isopropanol (3:2, v/v) with a Biospec Model 985-370 Tissue Homogenizer (Biospec Products, Inc. Racine, WI, USA) and centrifuged at 4000 g for 5 min, as described by Hamama et al. (2003). The three extractions were combined and the hexane-lipid layer was separated from the combined extract after shaking with 10 mL of 1% solution of equal amounts of $CaCl_2$ and NaCl in 50% methanol. The hexane lipid layer was removed by aspiration and dried over anhydrous Na_2SO_4. The oil percentage (g/100 g dry basis) was determined gravimetrically after drying under vacuum at 40 ^{o}C and stored under nitrogen at - 10 ^{o}C until analysis.

Sugars were extracted from ground buckwheat sample (1 g) and analyzed by HPLC following the methods optimized by Johansen et al. (1996). Sugars in the extracts were identified by comparing their retention times with standard sugars. For quantification, trehalose was used as internal standard and the sugar concentration was expressed as g/100 g meal (Bhardwaj & Hamama, 2016).

2.4 Statistical Analysis

All data were analyzed as a Randomized Complete Block Design using version 9.1 of SAS (SAS Institute, Inc., 2014) using ANOVA with 5% level of significance. Composition traits of buckwheat from this study were compared to literature values for alfalfa hay, perennial peanut, and soybean forage.

3. Results and Discussion

3.1 Fresh and Dry Yields

Results indicated that buckwheat varieties and planting dates contributed significantly towards variation for fresh yield and several compositional traits (Table 1). In general, interactions between varieties and planting dates were not significant. Details of results from this preliminary study on buckwheat grown in Virginia during 2015 along with values for other forages from literature, are presented below:

Table 1. ANOVA (Mean squares) for yield and composition traits of buckwheat grown during 2015 at Ettrick, Virginia (USA)

Source	Mean squares		
	Variety[1]	Planting date[1]	Variety*Planting date
Fresh yield kg/ha	5659469**	1841452*	748719
Dry yield kg/ha	24603261	17472547	5785942
Oil	3.05**	0.34	0.06
Protein	1.89	13.88	0.77
ADF	37.52	8.56	0.14
NDF	28.09	9.61	2.10
Sucrose	0.18	0.36	0.38
Fructose	0.06	9.99**	0.79
Glucose	1.36	71.21**	8.84
P	0.003	0.342**	0.001
K	0.016	0.566**	0.124
Ca	0.029	3.940**	0.096
Mg	0.009	0.744**	0.023
S	0.000	0.001	0.001
Na	0.000	0.001**	0.000
B	4.000	90.25**	0.250
Zn	16.000	289.00**	0.250
Mn	0.062	203.06	18.06
Fe	121.00	13689.00**	552.25
Cu	0.062	0.062	0.062
Al	72.25	1640.25	961.00

Note. [1] Two buckwheat varieties (Mancan and Koto), three planting dates (June 22, July 20, and August 14).

*, **: Significant at 5 and 1 percent levels, respectively.

Table 2. Biomass traits of buckwheat grown during 2015 at Ettrick, Virginia (USA)

Biomass trait	Varieties[1]		Planting dates[2]		
	Koto	Mancan	June 22	July 20	August 14
Fresh yield kg/ha	5669 a	4697 b	5642 a	5223 ab	4685 b
Dry yield kg/ha	1141 a	973	1149 a	1104 a	917 a
Oil*	6.1 a	5.2 b	5.77 a	5.48 a	Not available
Protein*	21.1 a	20.4 a	21.7 a	19.8 a	Not available
ADF*	29.8 a	32.9 a	32.1 a	30.6 a	Not available
NDF*	37.1 a	39.7 a	39.2 a	37.6 a	Not available
Sucrose*	1.4 a	1.6 a	1.39 a	1.69 a	Not available
Fructose*	3.2 a	3.3 a	2.49 b	4.07 a	Not available
Glucose*	7.6 a	8.2 a	10.01 a	5.80 b	Not available
Phosphorus*	0.53 a	0.50 a	0.66 a	0.37 b	Not available
Potassium*	2.84 a	2.78 a	3.00 a	2.62 b	Not available
Calcium*	2.40 a	2.31 a	2.85 a	1.86 b	Not available
Magnesium*	1.22 a	1.17 a	1.41 a	0.99 b	Not available
Sulfur*	0.25 a	0.25 a	0.26 a	0.25 a	Not available
Sodium**	0.04 a	0.04 a	0.05 a	0.03 b	Not available
Boron**	29.0 a	28.0 a	30.9 a	26.1 b	Not available
Zinc**	35.6 a	33.6 a	38.9 a	30.4 b	Not available
Manganese**	36.4 a	36.5 a	32.9 a	40.0 a	Not available
Iron**	149 a	144 a	176 a	117 b	Not available
Copper**	9.00 a	8.87 a	9.00 a	8.87 a	Not available
Aluminum**	102 a	106 a	114 a	94 a	Not available

Note. [1] Means based on three planting dates and four replications; [2] Means based on two varieties and two replications.

*: Percentage values on dry matter basis; **: Values as parts per million.

Table 3. Composition traits of buckwheat and crops relative to forage potential

Biomass trait	Buckwheat grown at VSU during 2015	Alfalfa hay[1]	Perennial peanut hay[1]	Soybean forage[2]
Oil*	5.6	Not available	Not available	6.1
Protein*	20.8	19	14	19.8
ADF*	31.4	32	32	38.2
NDF*	38.4	40	42	38.2
Sucrose*	1.5	Not available	Not available	Not available
Fructose*	3.28	Not available	Not available	Not available
Glucose*	7.91	Not available	Not available	Not available
Phosphorus*	0.52	0.2	0.2	Not available
Potassium*	2.81	1.8	1.4	Not available
Calcium*	2.36	1.3	1.3	Not available
Magnesium*	1.19	0.4	0.5	Not available
Sulfur*	0.25	Not available	Not available	Not available
Sodium**	0.04	Not available	Not available	Not available
Boron**	28.5	Not available	Not available	Not available
Zinc**	34.6	30	34	Not available
Manganese**	36.4	Not available	Not available	Not available
Iron**	146	Not available	Not available	Not available
Copper**	8.94	12	6	Not available
Aluminum**	104	Not available	Not available	Not available

Note. [1] From Meyer et al. (2010); [2] From Lundray et al. (2008).

*: Percentage values on dry matter basis; **: Values as parts per million.

Biomass yield in these experiments averaged 4784 pounds fresh weight and 1000 pounds dry matter per acre. Biomass yield of KOTO variety was slightly superior to that of Mancan variety. Similarly, biomass yield from June planting was superior to that from late planting dates.

Buckwheat biomass contained approximately 21 percent protein and approximately 6 percent oil (Table 2). Values of various quality traits of buckwheat biomass are presented in Table 2. Concentrations of several forage quality traits in buckwheat forage was affected by planting date (Fructose, Glucose, P, K, Ca, Mg, Na, B, Zn, and Fe). In general, earlier planting date of June 20 resulted in significantly higher values for these traits except for concentrations of fructose and Mn in which case the values from later planting date of July 20 were significantly higher than those from the earlier planting date of June 22. Despite these differences, we observe that forage quality of buckwheat forage, produced in Virginia, was acceptable.

A comparison of buckwheat forage with that of alfalfa, perennial peanut hay, and soybean is presented in Table 3. Buckwheat forage had higher protein concentration than other forages whereas oil concentration of buckwheat forage was lower than that in soybean forage. Both ADF and NDF concentrations in buckwheat forage were lower than those in all other forages. Concentrations of P, K, Ca, Mg, and Zn were higher in buckwheat forge as compared to those in alfalfa hay and perennial peanut hay. Concentration of Cu in buckwheat forage was intermediate between that of alfalfa hay and perennial peanut hay.

We have previously reported (Bhardwaj, 2013; Bhardwaj et al., 2010) forage quality of two new crops, Tepary bean (*Phaseolus acutifolius* A. Gray) and white lupin (*Lupinus albus* L.). Both of these are legume crops as compared to non-legume buckwheat. Tepary bean forage from 59 days old crop contained 21.4 percent protein, 37.5 percent ADF, 41.1 percent NDF, and 1.12 percent fat. Mean values of P, K, S, Ca, Mg, and Na (% dry matter) in tepary bean forage were 0.28, 2.5, 0.28, 2.11, 0.54, and 0.05, respectively. Mean values of Fe, Al, Mn, Cu, Zn, and B (mg kg^{-1}) were 307, 229, 359, 9.3, 39.5, and 20.9, respectively (Bhardwaj, 2013). White lupin forage during 2003-04 crop season (Approximately 180 days old) had a mean ADF content of 23.7 percent with a range of 17 to 41 percent and a mean crude protein content of 18.7 percent with a range of 13 to 29 percent (Bhardwaj et al., 2010). These results indicate that, in general, quality of buckwheat forage is acceptable and a potential use of this crop especially because buckwheat can be harvested in about 30 days and can be grown with minimal inputs.

Based on these results, buckwheat forage seems to be a desirable forage. There is a lack of crop options for planting during late summer if/when summer crops such as corn and soybean fail due to drought. Buckwheat has tremendous potential for successful production during this period especially as a short-season forage crop. These results are only from one year and would need to be repeated over years and locations to critically characterize the potential of buckwheat as a forage crop.

El-Nashaar et al. (2009) indicated that concentrations of Al, P, K, and S (ppm) in switchgrass (44 to 111, 1297 to 5656, 6481 to 15806, 467 to 1133, respectively) are suitable, generally, for its thermochemical conversion to ethanol. Berchem et al. (2017) indicated that sucrose content in corn stalks varied from 0.7 to 11.5% with an average of 7.05%. Concentrations of Al, P, K, and S (ppm) in buckwheat biomass, in our study, were (104, 5200, 28100, and 2500, respectively) are quite comparable to those reported by El-Nashaar et al. (2009). Sucrose concentration of buckwheat biomass in our study was 1.5%. Based on these observations, we suggest that buckwheat biomass may also be a potential feed stock for bio-ethanol. This aspect needs to be explored further.

Our results indicate that buckwheat could be developed as a short-season, summer forage crop in Virginia and the Mid-Atlantic region of United States. This crop could also be a great help to bees as it could provide an alternative source of nectar. Seemingly, buckwheat can be grown as a nectar source and then harvested as a forage upon cessation of flowering. Additionally, buckwheat biomass may also have potential as an ethanol feedstock similar to use of corn stover.

4. Conclusions

This study indicated that buckwheat (*Fagopyrum esculentum* Moench, Family Polygonaceae) is a potential forage crop in mid-Atlantic region of the United States of America since agro-climatic conditions in Virginia are representative of those in mid-Atlantic region. Additionally, buckwheat as a summer crop could also support bees and other pollinating insects by providing a nectar source. Buckwheat biomass may also have potential as a feedstock for synthesis of bio-ethanol.

Acknowledgements

Authors are thankful to Virginia Agricultural Council for supporting this research with financial assistance. Authors are thankful to Virginia State University and US Department of Agriculture (NIFA/Evans-Allen Program) for their support of this study.

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