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Evaluation of Hydroponics Performance and Nutritive Value of Different Oat *(A. sativa)* Forage Varieties in Wollega University, Western Ethiopia

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Abstract: The experiment was conducted to evaluate hydroponics yield performance and nutritive value of different oat (*A. sativa*) for age varieties in Wollega University. There were two experiments conducted. The first one was undertaken to evaluate four oats varieties for forage yield and nutritive values. The second was executed to observe effects of watering frequency and harvesting dates on the same parameters mentioned above. In both cases completely randomized design (CRD) was used with three replication to manage the experiments. The results showed that there were no significant differences ($P>0.05$) among varieties of oats as an effect of frequency of irrigation on fodder yield, fresh yield, plant height, leaf weight, stem weight and leaf to stem ratio. There was significant effect ($P<0.01$) of dates of harvesting on hydroponic fodder yield, plant height, leaf weight, stem weight and leaf to stem ratio. The highest dry fodder yields were harvested at 10 days after planting and consistently decreased until 14 days of planting. The highest plant heights were observed at 14 days while the lowest were for 10 days of harvesting. Except for Ash and dry matter (DM) values that were not affected ($P>0.05$), there were significant differences ($P<0.01$) in crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent bound lignin (ADL) contents of the oats varieties. The oat variety, V-6710, contained the highest CP (23.4%), lowest fiber and lignin contents and relatively had better *in vitro* digestibility. It can be concluded that there was no biomass yield difference among oats variety. Harvesting hydroponic oats at 10 days after planting can give best DM yield and leaf to stem ratio. The oat variety, V6710, has given the most nutritious forage among the others.

Key words: Hydroponics · Nutritive Value · Oats · Varieties · Wollega University

INTRODUCTION

Ethiopia has the largest livestock population in Africa. The total livestock population for the country is estimated to be about 59.5 million cattle, 30.70 million sheep, 30.20 million goats, 2.16 million horses, 8.44 million donkeys, 0.41 million mules and about 1.21 million camels in the sedentary areas of the country [1]. In the country, there was recent report that about 60-70% of the livestock productivity was affected by feeds [2]. However, due to increase in human population there was wider cultivation of grazing land for food crops which in turn resulted in low native pasture production. In this regard, the chance of obtaining green fodder for livestock was decreased and for crop residues enhanced. Green fodder is an essential component of the ruminants' ration to enhance their productive and reproductive performance [3].It is a fact that feeding animals is deficient without including green fodder in their diets [4].

The dominant feed resources in Ethiopia are native pasture and crop residues [1]. Such feeds are poor in nutritive values and one of the major problems on livestock production in Ethiopia is the low quality of forages [5] that are tropical types (C_4 grasses) in characteristics. However, the major constraints in production of green fodder are decreasing land size for fodder cultivation and high cost of fertilization [6]. Furthermore, the non-availability of quality fodder round

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the year aggravates the limitations of the sustainable animal farming. Although urban and pre-urban dairying is common in the country, land limitation in urban areas resulted in difficulty of forage production mainly for ruminants. Similarly, there is severe shortage of feed for urban dairy production in almost all towns of Ethiopia. Unlike monogastric animals, ruminants cannot be sustained on cereal grains alone and needs to change cereals into herbage through germination. Due to the above constraints and the problems faced in the conventional method of fodder cultivation, hydroponics is an alternative technology to grow fodder for farm animals [7-9].

The hydroponics green fodder is produced from forage grains that are germinated and grown for short period of time inside special growing rooms, provided with the appropriate growing conditions [10]. Encroachment of grazing lands for wider cultivation of cereal crops creates an opportunity for hydroponic methods of quality forage production for ruminants from these cereals. Growing hydroponics fodder also enhances protein and vitamin content of cereal grains diets and improve animal performance [11, 12]. Hydroponic fodder has a short growth period (around 7-10 days) and requires a small piece of land for production [13]. Development of this planting system has enabled the production of fresh forage from oats, barley, wheat and other grains [11]. Even though barely, wheat and maize are suitable for hydroponic fodder production in tropical condition they are used for human consumption in Ethiopia. Hence the use of oats (*A. sativa*) is more suitable for hydroponic fodder production because it was not used for human consumption in the country. This study, therefore, was conducted to Evaluate hydroponics fodder yield performance and nutritive values of different oat (*A. sativa*) varieties in Wollega University.

MATERIALS AND METHODS

Experimental Site: The study was conducted from January 2018 to May 2018 in Wollega University, East Wollega Zone of Oromia regional state, Western Ethiopia. The University is located 328 km west of Addis Ababa, the capital city of Ethiopia. Its geographical coordinates are 10° 0' 0" N latitude and 37° 30' 0" E longitude. The average air temperature of the area is 21°C. The area receives the minimum and maximum rainfall of approximately 1376 mm and 2037 mm, respectively and the average annual rain fall is 1706 mm. Altitude of the area ranges from 1200-2342 m above sea level [14].

Frequency of Watering and Hydroponics Fodder Yield of Oats Varieties: This was the beginning experiment before starting harvesting dates experiment of oats varieties. This frequency of watering of the seeds was done for fourteen consecutive days. Seeds of the oat V8237 were sown in the planting trays, which have holes at the bottom, to allow drainage of excess water from irrigation. The treatments were formulated based on other reports that trays containing seeds were irrigated manually with tap water twice a day (Early in the morning and late in the afternoon) [15]. Since there was no frequency of watering experiment done on oats, it was extrapolated from barley based on seed sizes. Drained water out of irrigation was collected in plastic containers which were placed under each planting tray to avoid water logging [16].

Treatments for Frequency of Watering Experiment: V8237 watering was applied for 30 sec in every 2h interval of a day.

V8237 watering was applied for 30 sec in every 4h interval of a day.

Harvesting Dates and Hydroponic Fodder Yield of Oat Variety: The experiment was terminated after 14 days from frequency of watering experiment. At harvest time, the following data were recorded per tray: total fresh and dry matter yield of fodder and ratio of produced green fodder to the initial planted seeds weight were computed. A representative fresh plant samples (About 150 grams) from every tray were taken at harvest and dried at 105°C in the oven for 48 hours for DM yield determination. There were also other reports that harvested at 8, 12 and 16 days in hydroponic sorghum verities KD4 [17].

Treatments for Harvesting Dates Experiment

- V8237 oat harvesting at 10 days of seeding.
- V8237 oat harvesting at 12 days of seeding.
- V8237 oat harvesting at 14 days of seeding.

Agronomic Data Taken

Seeding Date: the Date at Which All Oats Varieties Were Prepared, Seeded and Started Watering: Leaf weight (Grams): During harvesting ten plants were randomly selected per tray and leaves were trimmed using razor blade and all the leaves weighed fresh on spot. All the leaves weighed together divided by ten gives individual plants average leaf yield.

Stem Weight: The same procedure was used to determine stem weight (g),as in leaves weight, for individual oats plant harvest.

Leaf: stem ratio: was calculated by dividing total leaf weight by total stem weight.

Total Fodder Yield: At harvesting total weight of green fodder obtained was calculated by taking fodder and tray weight together. The try weight of subtracted as follows:

Total fodder weight = fodder and tray weight – tray weight (1)

Chemical Analysis: Partial DM was determined by drying the samples at 60°C in oven for 48 h [18]. After drying each part of the samples ground to pass 1 mm mesh screen sieve and stored for chemical analysis and *in vitro* DM digestibility [19]. Hydroponic samples were analyzed according to the procedures of AOAC [20] for DM and ash determination. The Nitrogen (N) content was determined by micro Kjeldahl method. Crude protein (CP) was calculated as N×6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al*. [21] with using sodium sulfide by ANKOM 200 Fiber Analyzer were done at Debre Birhan Agriculture Research Center, (DBARC).

***In vitro* DM Digestibility:** *In vitro* DM digestibility of hydroponic oat was determined according to two-stage [22] technique as modified by Van Soest *et al*. [21], where a second stage (Rumen liquor-pepsin digestion) was substituted by neutraldetergent extraction to simulate true digestibility was done at Holeta Agricultural Research Center (HARC).

Design for Hydroponics Experiment: There were two experiments conducted. The first was to observe effects of irrigation frequency and harvesting dates on fodder yield and some agronomic traits. The second one was undertaken to evaluate four oats varieties (V-5453, V-5518, V-6710 and V- 8237) on fodder yield, yield related components and nutritive values. In both cases, the completely randomized design (CRD) was used with three replication to manage the experiments.

Statistical Analysis: The data on biomass yield and yield components and chemical compositions were analyzed using the statistical package, SAS [23]. Whenever the ANOVA declares significant difference among treatments, Tukey Honestly Significant Difference test (α=0.05) was used to compare means. The model used in both experiments was:

$$Yijk = \mu + \tau i + \varepsilon ijk \quad (2)$$

where, μ=overall mean of the population; τi= the i^{th} treatment effect and εijk=random error associated with yij.

RESULTS AND DISCUSSION

Effect of Frequency of Watering on Fodder Yield and Related Traits: The result of effect of frequency of watering on hydroponic fodder yield and yield related agronomic traits of oat were given in Table 1. The results showed that there was no significant difference (p>0.05) between treatments in all fodder yield and yield related components as effect of frequency of watering. However, there was only numerical difference between watering at 2hr and 4hr interval. The average green forage yields were 0.413 and 0.389t/ha for one production cycle for 2hr and 4hr watering interval, respectively. In the present study, fresh weight of green fodder was increased about 3.4 times the original seed weight, after sprouting for 14 days at 2 hrs interval. Dung *et al*. [24] observed 3.7 times increase in fresh weight on 7 days for hydroponics barley fodder by using 2hr interval. It is obvious that oats and barley were incomparable but there was no access for information on oats hydroponic fodder evaluation. Hence we were forced to cite related cereal grains at points where they share similar principles. In addition, Ghazi *et al*. [15], reported that fresh weight of green fodder increased about 4.5 times its original seed weight, after sprouting barley grain for 6 days by spraying seeds manually with tap water twice a day (Early in the morning and late in the afternoon) in hydroponic barely. This increase in fresh weight of forage was due to the large uptake of water during germination. Abdal Rahim and Saidi [25] showed that after sprouting, 6.5kg of hydroponic barely yield was harvested /kg of barely seed by using tap water irrigation twice daily. This was higher than present study due to use of different species, different weather condition and different weight (g) of seed used at sowing, seed quality and variation in light intensity, water quality (PH), seeding density and temperature.

In present study there was only numerical difference in dry fodder yield between water irrigation of 2hr and 4h interval with the mean of 0.107 and 0.1t/ha, respectively which was lower than initial weight of the original seeds. There was little loss of DM in the hydroponic

Table 1: Effect of frequency of watering on hydroponic fodder yield and yield related components

	Frequency of watering			
Parameters	2 hour	4 hour	SE	P-Value
Fresh yield(t/ha)	0.413	0.389	34.4	0.69
DMY (t/ha)	0.107	0.1	9	0.69
Plant height (cm)	12.4	12.9	0.09	0.08
leaf weight (g)	0.36	0.39	0.018	0.36
Stem weight (g)	0.77	0.68	0.095	0.56
LSR	0.46	0.49	0.03	0.68

LSR = leaf to stem ratio; DMY = Dry matter yield;
SE = Standard error; t/ha = tone per hectare

Table 2: Effect of date of harvesting on hydroponic oat fodder yield related components

	Dates of harvesting				
Parameters	10 days	12 days	14 days	SE	P-Value
Fresh yield (t/ha)	0.29^{c}	0.39^{b}	0.42^{a}	2.08	0.0001
DMY (t/ha)	0.11^{a}	0.09^{b}	0.08^{b}	0.45	0.0001
Plant height (cm)	7.5^{b}	10.6^{a}	10.9^{a}	0.097	0.0001
Leaf weight (g)	0.24^{b}	0.32^{a}	0.33^{a}	0.007	0.001
Stem weight (g)	0.2^{c}	0.64^{b}	0.72^{a}	0.004	0.0001
LSR	0.47^{b}	0.5^{a}	0.46^{b}	0.005	0.01

LSR = leaf to stem ratio; DMY = Dry matter yield; SE = Standard error; t/ha = tone per hectare; a b c = Means with different superscript letters within rows differ at $p<0.05$.

fodder than in original seeds [18]. It was reported that DM content of the seeds decreased during the sprouting [18] when compared to the original seeds. This gradual decrease in DM during sprouting process could be due to leaching and oxidation of substance from seed.

In present investigation there was no difference between treatments in plant height. This is similar for leaf weight, stem weight and the average stem weight was 0.77 and 0.68 g for 2 hrs and 4 hrs interval, respectively. In present investigation there was no difference between treatments in the LSR.

Effect of Date of Harvesting on Fodder Yield and Yield Related Traits: The result of effect of date of harvesting on hydroponic fodder yield and yield related components were given in Table 2. There were differences among treatments in fodder yield and yield related traits. The mean fresh fodder yield sat 10, 12 and 14 days of harvesting were 0.297, 0.391 and 0.416 t/ha, respectively. On the 10^{th} days of harvesting the forage of all oats was not fully grown but at 14^{th} days of harvesting had higher biomass value. This indicates that longer harvest time will result in higher biomass production according to this particular experiment. This shows the oats v-8237 herbage growth depends on availability of nutrient in seeds only for 14 days. Under condition of optimum humidity, oxygen and warmth the sugar was used for cell wall synthesis and to provide energy for growth [26]. According to Peer and Leeson [27] fresh weight increased 5.7 times the original seed weight, after sprouting for 7 days. Which were higher than the present report 3.4 times after 14 days may be due to the difference in seed type used, temperature, in the study area and housing which affects light intensity to allow growth of hydroponic fodder. Since oat bran is hard, it prevent quick moistening of seed coats and hence retards germination date and thereby harvesting date in that the harvesting time reached 14 days in our experimental cases.

The present results have shown that there was significant difference among the treatments in dry matter yield. The average dry fodder at 10, 12 and 14 date of harvesting were 0.107, 0.099 and 0.077t/ha, respectively. Longer harvested time increase biomass production but decrease dry mater and dry fodder yield. This gradual decrease in DM during sprouting process might be due to leaching and oxidation of nutrients from the seeds.

There were significance differences ($P<0.0001$) among treatments in plant height as effect of date of harvesting. For 10, 12 and 14 date of harvesting, the meanplant height were 7.5, 10.6 and 10.9 cm, respectively. Since the herbages of all oat was not well grown at 10 days of harvesting, the plant height at 14 date of harvesting had higher value. Longer harvest time will help the plant use nutrient in the seed of oats and hence the plant continued to increase in height.

There were also significant differences ($p<0.001$) among treatments in plant leaf as influenced by dates of harvesting. As time of harvesting increased photosynthesis continues until nutrient in the seed lost. As photosynthesis continue growth of plant increase and plant leaf also increases. This means longer harvest time could bring higher plant leaf production. The 14 days harvest time increased the plant stem significantly ($P<0.0001$). There were also differences among treatments in LSR. Since plant LSR is the ratio of plant leaf to plant stem, as harvesting time increase the stem weight increases as compared to leaf weight and hence the plant harvested at 12 day have higher plant LSR and plant harvest after 14 days have lower coefficients.

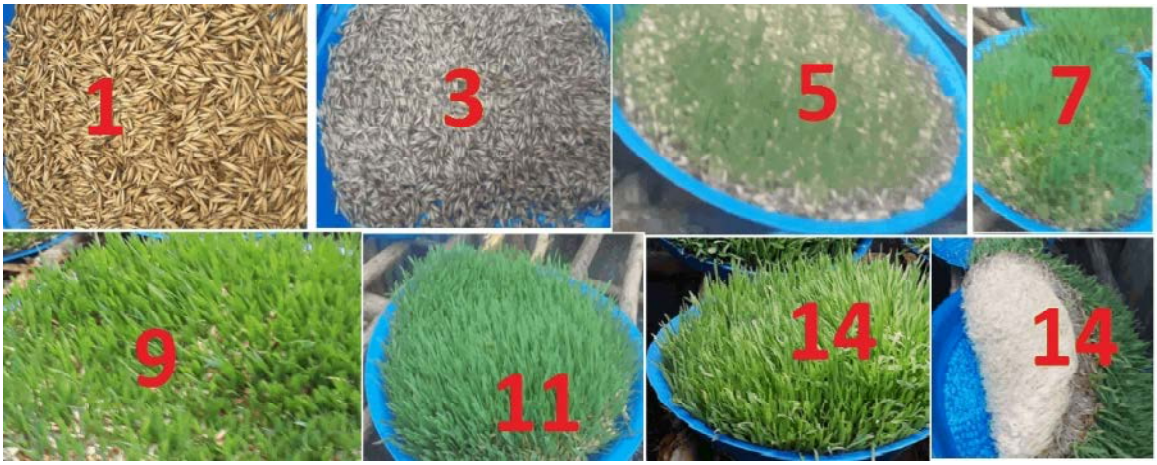

Fig. 1: Effect of date of harvesting on hydroponic performance of oat

Effect of Different Oat Varieties on Biomass Yield and Yield Related Components: The effect of different oat varieties on yield and yield related component were given in Table 3. The analysis of variance ($p>0.05$) indicated that none of the measured parameters were affected by difference in varieties. The average green forage yields were 1.73, 1.79, 1.89 and 1.95 t/ha for V6710, V8237, V543 and V5518 and in one production cycle. According to Peer and Leeson [27], fresh weight increased from 5.7 times of the original seed weight, after sprouting for 7 days. This increase in fresh weight of forage was due to the large uptake of water during germination. Naik and Singh [28] noted yields of 5–6 folds on fresh basis (1 kg seed produces 5–6 kg Hydroponic maize).In other places [29] disclosed a production up to 10 kg of fresh fodder out of 1 kg of barley seeds. Similar yield was noted for similar, material that 1 kg of barley grains produced a fodder yield ranging from 7 to 10 kg [27, 30] which is higher than the result of current study. Had it been based on grain size and stock size, we expect maize to be more in biomass yield than barley but it depends on the situation under which the experiment was managed so that the result could vary.

The varieties of oats did not show difference on dry matter yields ($p<0.05$). The average dry fodder yields were 0.457, 0.467, 0.471 and 0.483 for V-8237, V- 6710, V-5518 and V-5453 respectively which were lower than initial weight of seed. There were some dry matter losses (DML) were found. In similar way for fresh and dry matter yields measured, the leaf weight ($p>0.05$) and stem weight and then leaf to stem ratio (LSR) were all did not significantly differ. Almost all the justifications made for fresh yield of the same fodder oats variety works also here for dry matter yields obtained.

Table 3: Effect of different oats varieties on Biomass yield and some agronomic traits

	Oats varieties					
Parameters	V6710	V5518	V5453	V8237	SE	P-value
DMY (t/ha)	0.47	0.47	0.48	0.46	0.54	0.99
DM (%)	27	24	26	26	0.73	0.85
Plant height (cm)	10.6	11.5	11	10.4	0.42	0.36
Leaf weight (g)	0.9	1.1	0.9	1.2	0.16	0.56
Stem weight (g)	0.61	0.72	0.61	0.72	0.11	0.79
LSR	1.6	1.58	1.5	1.6	0.12	0.79

LSR = leaf to stem ratio; DMY = Dry matter yield;
SE = Standard error; t/ha = tone per hectare

Fig. 2: Hydroponically grown oat varieties in Wollega University

Effect of Hydroponically Grown Oat Varieties on Fodder Chemical Composition: In addition to quantitative evaluation (Yield) testing the nutritive potential of forages is highly important as it shows nutrient content of feeds. Likewise, Table 4 shows chemical composition of fodder as an effect of hydroponic oat varieties. There were differences among treatments in chemical composition of oat varieties. The CP contents were also differed and the values were 18.9, 19.6, 20.8 and 23% for V5453, V5518, V8237 and V6710, respectively in one production cycle. Oat variety V6710 scored higher CP content whereas the

Table 4: Effect of hydroponic oat varieties on chemical composition of the fodder

	Oats varieties					
Parameters (%)	V-6710	V-5518	V-5453	V-8237	SE	P-value
DM	92	92	91	91	0.02	0.954
Ash	3.97	4.4	4.75	4	0.42	0.571
CP	23.4^{a}	19.6^{ab}	18.9^{b}	20.9^{ab}	0.87	0.045
NDF	39.5^{b}	51.8^{a}	47.1^{ab}	47.8^{ab}	1.83	0.017
ADF	27.5^{b}	39.9^{a}	35.8^{ab}	36.6^{ab}	1.92	0.018
ADL	5.9^{b}	9.2^{a}	8^{ab}	8.7^{a}	0.57	0.025
IOMD	53.9	49.3	40.8	55.8	-	-

DM = Dry matter; CP = crude protein; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; ADL = Acid detergent lignin; IOMD = *In-vitro* organic matter digestibility; SE = Standard error; a b Means followed by different superscript letters within treatments differ at $p<0.05$

variety V5453 scored lowest values. The average CP value for all varieties was 20.69%. According to Tilley and Terry [22] cited by Chinnam [31] the CP content of oat fodder was 20.7, which was almost similar to the present finding. Similarly, Snow *et al*. [32] reported a lower (16.13%) CP content for hydroponically grown other cereal fodders. Sneath and McIntosh [33] evaluated the composition of sprouted barley and reported that CP ranged from 11.38 to 24 % which was comparable with the present value of oats hydroponic fodder. Different researchers reported that CP content of different oat grain varieties [34] reported that it varies with range of 4.8% to 7.6% and with average of 6.2%. Since the average CP % of hydroponic in the present study oat fodder was 20.69%, it shows that sprouting cereal grain improves CP content.

The increase in protein content may be attributed to the loss in dry weight, particularly carbohydrates, through respiration during germination and thus longer sprouting time was responsible for the greater losses in dry weight and increasing trend in protein content [35]. According to Morgan *et al.* [36] as cited by and McIntosh [33] changes in protein contents occur rapidly from day 4 corresponding with the extension of the radicle (Root), which allows the mineral uptake. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrates reserves, thus increasing levels of CP [37]. The differences observed in protein content of hydroponic oat fodder observed in the present study could be attributed to the shift from cereal grain to hydroponic green fodder since the CP contents were higher in hydroponic oat fodder as compared to oat grain.

The cell wall contents (NDF and ADF) and ADL of the fodder produced from sprouting of different oats varieties has shown differences among treatments. The mean values of NDF were 39.5, 47,47.8 and 51.8, %for V-6710, V-5453, V- 8237 and 5518, respectively. The mean for ADL were 5.9, 8, 8.7 and 9.2% for V-6710, V-5453, V-8237 and V-5518, respectively. According to Singh and Oosting [38], feeds containing NDF values of less than 45% are classified as high, those with values ranging from 45% to 65% as medium and those with values higher than 65% as having low quality. In the current study, the NDF content of the oat variety V-6710 fulfills high quality forage criteria that it was below 45%; the rest varieties were in the medium quality classes. This confirms that the hydroponic oats fodder produced in the present study was expected to result in high intake when consumed by animals. The ADF values ranging from 27.5-39.9% for all oats varieties fodder was also in status which do not impair digestibility. In spite of its green, young and lush stage and low lignin content (5.9-9.2%) of the oats fodder in the present study, the *in vitro* OM digestibility could have been more than the observed values (40.78-55.78); however, it must be the residue of the previous grain hulls and the root structure of the sprouted oats fodder that reduced it.

CONCLUSION

The hydroponics fodder oats crude protein contents ranged between 19-23%, with the average (21%), this indicates that it can be used for supplementing basal feeds such as crop residues and native tropical pastures of low protein content. Its fiber contents such as NDF (48-51%), ADF (28-40%) and ADL (6-9%) contents showed that hydroponic oats fodder in the range of high to medium quality forage. There was no biomass yield difference among oats varieties. Harvesting hydroponic oats at 10 days after planting can give best DM yield and the oat variety, V6710, was identified as the most nutritious one among others.

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