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Effect of agro-ecology, soil physicochemical properties and fertilization on nutrient content, yield and degradability and disease resistance of three forage oat (*Avena sativa*) varieties

Abstract

Effects of physicochemical soil properties and altitude (Gummer=2925masl, Albazer=2400masl) on nutrient content and yields of oat varieties (Lamptone, CI8235 and CI8237) were evaluated. Representative soil samples were collected from randomly selected spots (20cm depth) of Albazer and Gummer. After three ploughing of land, oat varieties were sown (100kg seed/ha) on replicated plots; 100kg di-ammonium phosphate and 100kg urea per ha were applied in two splits. The plots were regularly weeded and supervised for disease. At maturity (161 and 141 d after sowing at Gummer and Albeza, respectively) whole plant from each plot was cut 2cm above the ground, seed with husk (SH) and straw separated and weighed and values extrapolated on hectare basis. Soil type in Gummer was silt and in Albazer clay. Gummer was more acidic than Albazer. Soil had higher cation exchange capacity (CEC) at Albazer than Gummer but the exchangeable acidity (EA) was more at Gummer than Albazer. Soil organic carbon (OC), dry matter (DM), organic matter (OM), total nitrogen (TN) and available phosphorus (AP) were more at Gummer than Albazer. Straw DM was nearly similar but OM was more at Gummer than Albezar. The lowest DM and OM content was from Lamptone SH but highest from CI8235 and CI8237 at Albazer. Crude protein (CP) content of oats was more at Albazer than Gummer. Highest straw CP was from Lamptone at Albazer and lowest at Gummer. CI8237 at Albazer had highest EE but Lamptone at Gummer the lowest. The EE content of SH at Gummer was higher than at Albazer. Lamptone SH was the lowest in NDF at Albazer but highest at Gummer. Higher DM, OM and CP yields were from Gummer than Albazer. The interaction effect was observed between agro-ecology and varieties nutrient content and yield. For CP content Albazer was better but for nutrient yields Gummer was efficient. CI8235 at Albazer had lowest digestibility while CI8237 at Gummer and Albazer had the highest. Less acidic and clay soil at low altitude favored yellow rust infection of oat. Optimum oat DM and nutrient yields and digestibility were obtained in Gummer which has silt and acid (pH of 5.45) soil with better OM, OC, TN and AP. Variety CI8235 was more productive and profitable followed by Lamptone. Thus before introducing oats to a new area, knowledge of soil physiochemical characteristics and suitable oat variety is important.

Keywords: soil property, oat varieties, straw, seed with husk, nutrient content, nutrient yield

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Introduction

Oat (Avena sativa, common name: Groats, herb oats, oat grass, oats, wild oats) grows well in dry waste lands, cultivated ground, meadows, and heavier soils although it prefers sandy or loamy soils. It requires good drainage but can grow in acidic soil (Tom and Patrick, 2006). According to Tom and Patrick (2006), oat straw contains protein (gluten), saponins, flavonoids, alkaloids, steroidal compounds, vitaminsB1, B2, D, E, carotene, starch, fat, minerals such as calcium, magnesium, and iron and trace elements like silicon and potassium. Oat is produced as a cash crop and feed crop. Usually oat has an economic advantage if used for livestock feed as hay or silage.[1] According to Tom and Patrick (2006), oat straw is important for the dairy for the dietary reduction of nutrient/energy/moisture density, and for the alteration of dietary cation to anion ratio in dry cow diets since it contain low potassium and inclusion of low potassium forages can aid in the prevention of milk fever in transition dairy cows. Straws are typically high in fiber and low in crude protein and energy making them excellent forage in situations where dietary energy or protein dilution is desired. The report of Muhammad et al.,[2] shows that oat has the potential for the production of high yield per acre (7.77 to 8.47ton DM/ha). Southern Nations, Nationalities and Peoples Regional State has large livestock number but their production and reproductive performance are too low mainly caused by lack of quality feed.[3] According to CSA,[4] major feed sources are: green fodder (grazing about 69.63%): crop residue (23.17%): hay (1.82%) and by-products (1.18%). On the other hand, very small amount of improved feed (0.39 %) is used as animal feed. Sample survey in three Districts of Werabe Research Center mandate area shown that 368 cattle, 411 sheep, 129-goat and 84-donkey died due to feed and water scarcity and 25697 cattle and 11897sheep couldn't recover from the hardship.[5] The condition was serious in highland areas because there is land scarcity, low crop residue and green feed production. Efforts have been made by Regional Bureau of Agriculture together with Southern Agricultural Research Institute (SARI) to improve the quality and quantity of feed through evaluation of adaptability of different forage crops in different agro-ecologies. Among which, adaptation and evaluation of grass forages such as oat varieties (*Avena sativa*) in two agro ecologies (mid and high altitude) through participatory testing was conducted and taken as the possible solution for alleviating feed shortage and determine the best situation for oat production. This experiment was thus conducted to determine effects of fertilization, agro-ecology and soil physiochemical traits on adaptability, nutrient yield and disease tolerance of oats.

Materials and methods

Description of the Study Area: The study was conducted in Southern Nations, Nationalities and People's Regional State (SNNPRS) on two sites: Gummer located in Gummer District (about 210km south of Addis Ababa) of Gurage Zone and Albazer in Hulbareg District (about 180 km south of Addis Ababa) of Siltie Zone. Gummer has 234km2 area and is 2925m. a. s. l (cool). Hulbareg has 403km2 area and is 2400m. a. s. l (moist and dry). The mean annual rain fall of Gummer and Hulbareg ranges between 1200-1400mm and 700-830mm, respectively. Both Districts have two rainy seasons: between June-September and February-April. Mean temperature of Gummer and Hulbareg range between 16-21oC and 18-26oC, respectively. Gummer District has 18 rural administrative Kebeles among which, 2 are towns, whereas Hulbareg has 13 in rural and 1 town Kebele.

Soil sample collection: Representative soil samples were taken from Albazer and Gummer using auger. At different topography and slope gradient the experimental plots were demarcated on each site and five sub samples were collected at different spots randomly and composite samples were formed. Soil samples were collected at 20cm depth and kept in labeled plastic bags.

Then the soil samples were transported to Wolkite Sample Testing and Soil Fertility Improvement Center for physicochemical analysis. Land preparation: In both experimental sites, gross land of 22 M2 was demarcated. Topography difference of the two sites was minimized using land slop calculation. Demarcated land was ploughed by oxen in May. The second plough was just after one month. Third and last plough was done by digging using manpower for the purpose of loosening the coarse soil texture. Seed collection, preparation and sowing and plot management: Three varieties of oat called CI8235, CI8237 and Lamptone were obtained from Holeta Research Center. Before seeding, germination test was conducted using petridish. Inert materials, broken and deformed seed as well as soil were removed manually from the seed. Clean seed was kept in plastic bags until sowing date. Nine plots (3m x 2 m) were prepared at each site. The spacing between rows was 30cm apart and sowing depth was 2cm. For each plot, 60 g seed, 60 g DAP for single application and 60g urea for two times dressings was used. Seed was sown by drilling and the fertilizers were applied by drilling near by the seed. The seed and the fertilizer were covered by loose soil manually. Weeding was done manually 35 days after sowing date. Plots were protected from water logging using small water path furrow and at the same time half of the urea left was applied. This was done at dusk. Oat sample collection: Samples of whole oat were harvested at 161 and 141 days after sowing in Gummer and Albazer, respectively using a 1m x 1m plumber quadrate. The quadrate was thrown back on selected variety plots and the oats harvested about 2cm above the ground. Collected samples were weighed and then sun-dried on plastic sheet. The samples were thrashed separately on plastic sheet, and then weight of straw and seed recorded. Then 1kg of the straw and 1kg of the seed were sub-sampled and kept in separate sacks for laboratory analysis.

Chemical analysis

Dry matter (DM), organic matte (OM), ash, crude fiber (CF), crude protein (CP), ether extract (EE) and calcium (Ca) of forage samples were analyzed in the laboratory of National Veterinary Institute whereas, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and in vitro dry matter digestibility (IVDMD) were analyzed in Holeta Research Center. The representative samples were dried at 650C and ground in Thomas–Wiley Laboratory mill (Model 4) to pass through 1 mm sieve for chemical analyses and 2mm sieve for in vitro studies. Samples were analyzed for DM, OM, ash and EE according to AOAC.[6] The N content was determined by the Kjeldhal method and the CP content was calculated as N X 6.25. Neutral detergent fiber (NDF), ADF and ADL were analyzed according to Van Soest et al.,[7] Calcium and phosphorus were determined Spectrophotometric method. The IVDMD was determined using the two stages in vitro Tilley & Terry procedure[8] as modified by Van Soest & Robertson.[9] The soil chemical analysis was conducted using ISRIC.[10] Partial budget analyses: The three land types were assessed for comparative advantages based on the sample taken on 100M2 of land. The then labor cost of land preparation was taken, seed cost and management and estimated selling price were collected from market. In addition, the variable cost for each plot was recorded. Using procedure of Upton,[11] partial budget analysis was conducted for measuring profit margin of intercropping. Net income (NI) is the amount of money left when total variable cost (TVC) is subtracted from total return (TR). Change in net income (ΔNI) was calculated by subtracting change in total variable cost (ΔTVR) from change in total return (ΔTR). Marginal rate of return (MRR) measures the increase in net income (ΔNI) associated with each additional unit of expenditure (ΔTVC) and was calculated as MRR = (ΔNI/ ΔTVC) ×100) Data management and statistical analysis: The DM and OM yields from the quadrates were converted on to plot and then hectare-basis by multiplication using the correction factor 10,000 for hectare. The data on chemical composition, nutrient yield and in-vitro studies and soil mineral content were subjected to analysis of variance using General Linear Model (Univariate and multivariate) procedures of SPSS Version 22 (SPSS, 2014).[12] Means were compared using Duncan's multiple range tests. Means were declared significant at $p<0.05$. The model used for statistical analyses of the chemical composition of oat straw and seed from two varieties grown in the two agro-ecologies was: $Y_{ij} = \mu + \alpha_i + \theta_j + e_{ij}$; where: Yij = DM ,OM, ash, CP, EE, NDF, ADF, ADL, CF, Ca content DM, OM and CP yield and IVDMD; μ = overall mean; αi = effect of ith variety on nutrient content and yield (i= CI8235, CI8237 and Lamptone);θj = effect of jth agro-ecology (j= Gummer for high altitude and Albazer for middle altitude); eij = random error.

Results and discussion

Soil texture and mineral content of experimental sites: The texture and mineral content of soils of the two experimental sites were different (Table 1). The soil pH and cation exchange capacity (CEC) were higher but organic carbon (OC), organic matter (OM), total nitrogen (TN), available phosphorus (AP) and exchangeable acidity (EA) lower in Albazer than Gummer. Gummer has sandy and silt type of soil with less clay content than Albazer. Less acidic soil was in favor of CEC but not of EA. Albazer site was relatively less acidic than Gummer site. The higher the OC content the higher the

OM and TN but less in moisture content (MC). Higher amount of AP was found in silt than clay soils with higher TN and OC. Soil having higher OM also had higher TN. Moderate acidic and silt type soil at Gummer with higher OC, OM, TN, and AP gave better DM, OM and CP yields of oat per hectare. CI8235, CI8237 and Lamptone were more efficient in DM, OM and CP yields. Only one third of the nutrient yields of the varieties at Gummer were obtained at Albazer. The study of Muhammad et al.,[2] in Egypt showed the effect of season on pH, OM, TN and P where in 2011-2012 produced more (8.1, 0.77%, 0.042% and 7.2ppm) than in 2010-2011 (7.8, 0.73%, 0.039% and 6.6ppm, respectively). From their study, DM yield was much greater in 2010-2011 than 2011-2012 (8.47t vs 7.77t) but the re-growth cut of 2010-2011 was much lower than 2011-2012 (3.87t vs. 4.73t). From their result relatively lower pH (not acidic) value was in favor of DM, N and OM. The acidic soil (5.45 vs.5.6pH) in our study area was very close to the pH value that produced high DM, OM and CP yields. The higher DM yield reported by Muhammad et al.,[2] could be related to differences in rain fall (7.04mm vs 3.45mm) received during the growing period of 2010-2011 than 2011-2012. The variability of DM yields from the two cuttings and years when compared with the result in this study may be related to differences in varietal potential adaptability. Larry & Mark[13] and Silveira et al.,[14] added that as soil pH drops below 5.5, the concentration of soluble aluminum increases and becomes toxic to plant roots when it exceeds 1.0ppm. Below pH 5.2, the concentration of manganese also can become toxic to plants. Effect of low pH not only restricts on aluminum and manganese toxicity but affects microbe activity that have roles in recycling of soil nutrients through mineralization of organic matter and N fixation associated with forage legumes.

Table 1 Physicochemical composition (Mean + SD) of soil at Gummer and Albazer experimental sites

Soil mineral and texture	Experimental sites	
	Gummer	Albazer
pH-H2O(1:2.5)	5.45+ 0.004	5.6+0.022
Soil buffer pH	5.80+0.002	6.53+0.002
Cation exchange capacity (meq/100g)	14.46+0.001	16.36+0.001
Exchangeable acidity (meq/100g)	0.70+0.002	0.34+0.004
Organic carbon (%)	2.86+0.024	1.56+0.025
Organic matter (%)	4.93+0.033	2.69+0.101
Total nitrogen (%)	0.24+0.016	0.13+0.017
Moisture content (%)	3.96+0.070	4.71+0.110
Available phosphorus (mg/l)	0.72+0.025	0.40+0.025
Sand%	44.00+0.820	42.30+3.458
Clay%	16.00+0.819	31.70+2.120
Silt%	39.65+2.458	31.00+2.531

Row values with different superscript letters are significantly different ($p<0.05$); SE=standard error

Hence they recommended soil pH of 5.5 to 7.0 for optimum oat yield. Soil at Albazer was more of clay than at Gummer and hence probably more aluminum was found that could have hampered the growth of oat forage. Ross et al.,[15] reported that adequate P results in rapid growth and early maturity, which is important in areas where frost is a concern. Frequently, P enhances the quality of vegetative and root growth by increasing utilization of soil nutrients and moisture. The quantity of P in the soil solution was in the range of 0.3 to 3.0 kg/ha (0.3 - 3.0 lb/ac). Rapidly growing crops will absorb about 1 kg/ha (1.0 lb/ac) of P per day. Even though the quantity of P in soil is more, its availability is determined by the soil pH. In more acidic soils (pH <6.0), iron and aluminum increase which causes either a fixing or removing of P from the soil solution. This action greatly limits the availability of inorganic P to plants at soil pH less than 5.0. Generally, soil P is slightly more available to plants in a pH range of 6.0 to 7.5. Not only the pH value but also moisture and temperature affect the soil P availability. In cool, wet soils, P availability and movement are reduced. As a result, phosphate fertilizers are less accessible to crops in cool, wet spring conditions than in warmer, drier spring conditions. Phosphorus was more available at Gummer than Albazer and might have helped soil microorganisms in Gummer to produce more TN and DM in oat forage per plot of land. This idea is in agreement with findings of Haque et al.,[16] where in acid soils most of the applied P is sorbed by various constituents and P sorption increases with depth within the profile due to increasing clay contents. Thus P often increases nodulation and hence increases DM yield, crude-protein content, P concentration or uptake by plants, especially legumes.

Nutrient content and *in vitro* dry matter digestibly of oat straw from two agro-ecologies

As shown in Table 2 differences in the dry matter content of straws grown in the two agro-ecologies and among the three varieties were not significant ($p>0.05$). The DM content of oat straw at both sites was greater than earlier reports.[17,18] OM content of the three varieties' straw and seed with husk (SH) were significantly different ($p<0.05$). Lowest OM content was obtained from Albazer CI8237 but the highest was in Lamptone and CI8237 at Gummer. Organic matter content of the straw of all varieties was higher at Gummer than at Albazer. Crude protein content of straw of all varieties at Gummer particularly Lampton was lower than that of Albazer. The CP content of the three varieties at the two sites was much lower than earlier reports.[19] The CP content of CI8237 at Gummer was nearly same as earlier report.[19,20] Lowest EE was obtained from Lamptone straw at Gummer but highest from CI8237 at Albazer. The EE of CI8235 at Gummer, and Lamptone and CI8237 at Albazer were greater than earlier report (2.1) of Rossi[20] but the rest of the varieties had less than this value. The NDF content of Lamptone at Gummer was the lowest but that of CI8237 at Albazer was highest. All the NDF contents of the three varieties at all sites were greater than earlier reports.[19,20] Acid detergent fiber content of CI8237 at Gummer, and Lamptone and CI8237 at Albazer were lowest but that of Lamptone at Gummer was highest. The ADF content of oat measured before and after ensiling[19] is much lower than ADF contents of oat varieties in this study but they agree with the report of Redden.[18] The lignin content of CI8235 at Albazer was the lowest but that of CI8237 at Gummer and CI8237 at Albazer were highest. Lignin content of all oat varieties from the different sites were greater than the results reported by McCartney and Vaage[19] but nearly agrees with that of oat after ensiling reported by the same authors. There was an interaction effect between oat varieties and experimental site on nutrient content of the straw. The Ca content of all the varieties at the two sites was greater than earlier report.[18,20] The DM content of the three varieties straw was nearly similar while the OM and CP content of straw and seed with husk were varying significantly. Straw at Gummer had higher OM but at Albezar it had higher CP. Seeds with husk of both CI8235 and CI8237 at Albezar had better DM, OM and CP. Albazer elaborated its effect on CP content of Lamptone's straw. The straw of CI8235 at Albazer had the lowest digestibility coefficient but that of CI8237 at Gummer and Albazer had highest. The apparent digestibility of oat reported by McCartney and Vaage (1994) was greater than the values obtained in this study. The amount and level of lignin content in straw in all varieties at the two sites was negatively correlated with digestibility.

Table 2 Nutrient contents and in vitro dry matter digestibly (Mean ± SE) of the straw from three oat varieties grown in two agro-ecologies

Sites								
Nutrient (% DM)	**Gummer**			**Albazer**				
	Lampton	**CI8235**	**CI8237**	**Lampton**	**CI8235**	**CI8237**	**SEM**	**P-value**
DM (%)	97.77^{b}	97.47^{ab}	97.87^{b}	97.40^{ab}	97.47^{ab}	97.20^{a}	0.159	0.098
OM	92.65^{d}	91.76^{c}	92.247^{d}	88.97^{b}	89.09^{b}	88.49^{a}	0.15	0
Ash	5.11^{a}	5.711^{b}	5.62^{b}	8.429^{c}	8.379^{c}	8.711^{d}	0.04	0
CP	1.89^{a}	2.12^{a}	4.39^{b}	7.47^{e}	6.62^{d}	5.64^{c}	0.202	0
EE	1.11^{a}	2.71^{c}	1.84^{b}	3.12^{d}	1.87^{b}	6.85^{e}	0.044	0
CF	47.26^{e}	36.22^{d}	34.23^{c}	31.42^{b}	33.96^{c}	27.37^{a}	0.09	0
NDF	79.16^{a}	79.54^{b}	79.78^{b}	80.77^{c}	79.62^{b}	81.69^{d}	0.114	0
ADF	51.39^{c}	50.5^{b}	49.91^{a}	49.95^{a}	50.57^{b}	49.98^{a}	0.115	0
Lignin	4.35b	4.61^{c}	4.85^{d}	4.38^{b}	4.01^{a}	4.75^{d}	0.039	0
Ca	1.36^{a}	1.62^{b}	1.36^{a}	1.54^{ab}	1.54^{ab}	1.54^{ab}	0.065	0.072
Digestibility (% DM)								
IVDMD	45.30^{b}	46.29^{c}	47.49^{d}	45.22^{b}	44.09^{a}	47.24^{d}	0.201	0

ADF, acid detergent fiber; Ca, calcium; CF, crude fiber; CP, crude protein; DM,dry matter; EE, ether extract; IVDMD, in vitro dry matter digestibility; NDF, neutral detergent fiber; OM, organic matter; Row values with different superscript letters are significantly different ($p<0.05$)

Nutrient content and *in vitro* dry matter digestibility of seed with husk of oat varieties

Differences in nutrient content of seed with husk (SH) amongst varieties between agro-ecologies were significant ($p<0.05$; Table 3). The lowest DM and OM contents of SH were from Lamptone but highest from CI8235 and CI8237 at Albazer as compared to Gummer. More ash was found in straw than in SH. There was significant difference ($p<0.05$) between sites in nutrient content of SH. The lowest CP content was in CI8235 at Gummer but highest in that of CI8235 at Albazer. Straw had lower CP content than that of SH in all varieties at both sites. Experimental sites had influence on CP content within a variety. Gummer was suitable for CP production of SH in Lamptone and CI8237 at Gummer. High amount of CP was found in straw and SH of CI8235 and CI8237. Crude protein of the straw from all varieties was better at Albazer than at Gummer. Generally, Albazer was better than Gummer for CP content of both straw and SH. Ether extract (EE) contents of the three varieties were similar and lowest at Albazer were similar and the lowest but CI8235 and CI8237 at Gummer had highest EE. Ether extract of SH was greater than that of straw. Seed with husk had higher EE at Gummer than Albazer. The highest NDF was found in Lamptone at Gummer followed by CI8235 at Albazer but lowest in Lamptone at Albazer. The lowest Ca content was in both CI8235 and CI8237 at Albazer but highest in CI8237 at Gummer and Lamptone at Albazer. The CF, NDF and ADF contents of SH was nearly one third that of straw. The greater CF content of straw was at Gummer than Albazer but CF in SH was similar at both sites. Lignin content of straw and SH at both sites was nearly similar. Variation in apparent digestibility of SH was significant. CI8235 variety at Albazer had lowest SH digestibility coefficient but that of CI8237 at both sites was more digestible. The more digestible the straw is the better digestible the SH. Straw and SH of C18237 were highly digestible but it was less influenced by soil and altitude.

Table 3 Nutrient contents and *in vitro* dry matter digestibly (Mean ± SE) of seed with husk (SH) of the three oat varieties grown in two agro-ecologies

	Sites						SEM	P-value
Nutrient (% DM)	**Gummer**			**Albazer**				
	Lampton	**CI8235**	**CI8237**	**Lampton**	**CI8235**	**CI8237**		
DM	95.53^{b}	95.37^{b}	95.53^{b}	94.50^{a}	98.10^{c}	97.67^{c}	0.273	0.004
OM	92.39^{c}	91.38^{b}	92.43^{c}	89.81^{a}	94.02^{d}	93.23^{d}	0.204	0
Ash	3.34^{a}	3.98^{b}	3.10^{a}	4.69^{c}	4.08^{b}	4.42b^{c}	0.164	0
CP	10.90^{c}	8.29^{a}	10.92^{c}	9.26^{b}	12.78^{e}	11.54^{d}	0.128	0
EE	6.06^{b}	6.73^{bc}	6.93^{c}	5.31^{a}	5.34^{a}	5.34^{a}	0.222	0
CF	15.25^{d}	12.06^{b}	13.29^{c}	9.21^{a}	13.46^{c}	13.12^{c}	0.248	0

Table Continued....

Nutrient (% DM)	Sites							SEM	P-value
	Gummer				Albazer				
	Lampton		CI8235	CI8237	Lampton	CI8235	CI8237		
NDF	42.02^{d}		39.46^{b}	38.84^{a}b	38.33^{a}	40.18^{c}	39.46^{b}	0.213	0
ADF	15.15^{a}		15.86^{b}	15.63^{a}b	15.77^{ab}	15.37^{ab}	15.60^{a}b	0.205	0.225
Lignin	3.8		4.23	4.05	4.17	3.93	4.09	0.172	0.545
Ca	1.57^{bc}		1.40^{b}	1.92^{d}	1.76^{cd}	1.19^{a}	1.19^{a}	0.065	0
Digestibility (% DM)									
IVDMD	77.52c	76.57^{a}		77.32b^{c}	76.94^{ab}			0.165	0.009

ADF, acid detergent fiber; Ca, calcium; CF, crude fiber; CP, crude protein; DM,dry matter; EE, ether extract; IVDMD, in vitro dry matter digestibility; NDF, neutral detergent fiber; OM, organic matter; Row values with different superscript letters are significantly different ($p<0.05$)

Nutrient yield of the oat varieties

Nutrient yield of oats between experimental sites was variable ($p<0.05$, Table 4). The lowest total DM yield was observed in CI8237 at Albazer but highest in CI8235 at Gummer. All the DM yields obtained from the varieties at both sites were greater than earlier reports.[2,21] Lowest OM yield was in CI8235 at Albazer but highest in CI8237 at Gummer. Lowest CP yield was in CI8235 and CI8237 at Albazer but highest in Lamptone at Gummer. Better CP content in SH of Lamptone and C18237 at Gummer and CI8235 and CI8237 at Albazer improved SH digestibility. On the contrary, low CP content in CI8235 at Gummer and Lamptone at Albezar reduced SH digestibility. Generally, the nutrient yields were better at Gummer than Albazer. This may be due to higher TN, OM, OC and AP contents of and silt texture of the soil at Gummer. There was significant ($p<0.05$) interaction effect between experimental site and variety on nutrient yields. Nutrient yield was dependent on total forage biomass production of the varieties.

Table 4 Dry matter, organic matter and crude protein yields (kg/ha) of straw and seed from three oat varieties grown in two agro-ecologies

Nutrient yield (kg)	Sites							
	Gummer			Albazer				P-value
	Lamptone	CI8235	CI8237	Lamptone	CI8235	CI8237	SE	
Straw (DM/ha)	28707^{e}	32960^{f}	14339^{d}	9073^{c}	8882^{b}	8661^{a}	5.95	0
Seed (DM/ha)	8899^{d}	8111^{e}	7544^{c}	2384^{b}	2296^{a}	2769^{b}	2.33	0
Total (DM/ha)	37606^{d}	41071^{e}	21884^{f}	11457^{c}	11178^{b}	11429^{a}	7.49	0
Straw(OM/ha)	27205^{d}	31030^{e}	34931^{f}	8288^{c}	8118^{b}	7884^{a}	2.36	0
Seed (OM/ha)	8606f	7772^{e}	7300^{d}	2285^{b}	2182^{a}	2644^{c}	2.58	0
Total (OM/ha)	35811^{d}	38802^{e}	42231^{f}	10572^{c}	10301^{a}	10572^{b}	4.46	0
Straw (CP/ha)	5550f	723^{d}	1662^{e}	696^{c}	603^{b}	503^{a}	2.88	0
Seed (CP/ha)	1017f	705^{d}	862^{e}	311^{b}	325^{a}	327^{c}	1.16	0
Total (CP/ha)	6567^{e}	1428^{c}	2525^{d}	1006^{b}	828^{a}	830^{a}	3.21	0

Row values with different superscript letters are significantly different ($p<0.05$)

Disease condition

Varieties at Albazer site during flowering stage were affected by crown rust, also known as leaf rust, caused by a fungus, *Pucciniacoronataf avenae*. According to USDA,[22] the fungus is specific to cultivated oat, wild oat, and a few other wild grasses. The rust reduces oat yield and causes thin kernels with low test weight; factors which greatly reduce milling quality. USDA stated that late planting of oats followed by humid warm weather are the most favorable conditions for fungal development.

Partial budget analysis

The partial budget analysis is presented in Table 5. CI8235, Lamptone and C18237 at Gummer were 11, 6 and 4.6 times more profitable than corresponding varieties at Albazer, respectively. The net income earned from the three oat varieties at Gummer was 7.1 times more profitable than at Albazer. Moreover, Variety CI8235 was most profitable of all varieties followed by Lamptone at Gummer.

Table 5 Cost- benefit analyses of the three oat varieties cultivated in two agro ecologies

Parameters	Sites					
	Gummer			Albazer		
	Lamptone	CI8235	CI8237	Lamptone	CI8235	CI8237
Land rent (Birr)	4500	4500	4500	4000	4000	4000
Wage for preparation (Birr)	4000	4000	4000	3600	3600	3600
Wage for weed control (Birr)	3200	3200	3200	5470	5470	5470
Wage for harvest (Birr)	2400	2400	2400	3200	3200	3200
Wage for farm keeper (Birr)	3600	3600	3600	3600	3600	3600
a. Investment cost sum (Birr)	17700	17700	17700	19870	19870	19870
b. Income tax (2%)	1858	2161	903	319	210	218
Medicine cost (Birr)				1000	1000	1000
Sprayer wage (Birr)				120	120	120
c. Variable cost sum (Birr)				1120	1120	1120
DM yield (kg/ha)	37606	41071	21884	11457	11178	11429
DM content (%)	20.4	19.6	20.9	19.2	22.1	22.3
Estimated fresh weight (kg)	184343	209546	104708	59672	50579	51251
d. Gross income (0.6Birr/kg fresh oat)	110606	125728	62825	35803	30348	30751
e. Gross revenue (d-a)	92906	108028	45125	15933	10478	10881
f. net income (NI=e-(b+c))	91048	105867	44222	14494	9148	9543
∆ NI	89928	104747	43102	14494	9148	9543
∆TVC				1120	1120	1120
MRR				1294	817	852

DM, dry matter; MRR, marginal rate of revenue; NI, net income; ∆NI, change in net income; ∆TVC, change in total variable cost

Conclusion

In Gummer dry matter and organic matter content of Lamptone was improved but not of C18237 which had sandy and silt soil, low clay and moisture and higher OC, OM, TN and AP. Albezar's soil with low OC, OM, TN, and AP but more clay and moisture increased DM and OM contents in seeds of CI8235 and CI8237. Low OC, OM, TN, AP, with sandy and silt texture but more clay and moisture at Albazer improved CP in straws of CI8237 and seeds of CI8235. Digestibility of CI8237's straw at both sites was comparable but higher that of seed of Lamptone at Gummer and CI8235 at Albazer. Because of higher CP content of seed of CI8235 at Albazer, digestibility was improved. As compared to Gummer, at Albezar straw and seed of all oat varieties had better CP content except that of Lamptone's seed. In each sites, better CP content of the seed's was closely associated with digestibility. More clay but less sandy soil textures and low pH (<5.6), OM, TN and AP are not suitable for oat production. Yellow rust was favored by Albazer than Gummer. Gummer was more suitable for oat production; CI8235 had higher DM and nutrient yields, digestibility and profitability followed by Lamptone. Variety selection and soil physiochemical analysis are thus necessary before cultivating oat.

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None.

Conflicts of interest

The authors declared there is no conflict of interest.

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