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Role of Phosphorus and Carbohydrates in Regeneration of Forage Oat (*Avena Sativa* L.) Genotypes

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Abstract- Oat (Avena sativa L.), has received significant attention for its high content of phytochemicals, dietary fibers, and nutritional value. Taking one cut for fodder and grain production from regrowth improves the economic of multi cut fodder oats cultivation. However, information regarding the regrowth and biochemical constituents in these species is not available. The aim of the present study was to evaluate the biochemical and nutritional attributes for regrowth of oat genotypes. Two genotypes viz., HFO865 and HFO873 showed a respectively great increase in fresh weight from first cut (37.79 and 40.55 %) to second cut (87.56 and 72.66 %). Roots and stubbles had a high content of phosphorus and low content of total soluble sugars, thus indicating that phosphorus plays a definite role in regeneration. HJ-8 was observed to have the highest phosphorus content. Fructan decreased with cut systems, but still content was highest in HJ-8. In grains, maximum starch (59.44 %) was highest in HFO870. Crude protein was maximum in Dunav-1 (18.76 %), **β**-carotene was found highest in HJ-8 and Kent with the value of 110.31 **µ**g/g. The study indicates that Phosphorus, fructan and carbon content playing a crucial role in the regeneration of multi cut genotype (viz. HJ8).

Keywords: *fructans, multi cut, nutritional value, phosphorus, regeneration.*

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I. Introduction

Oat (*Avena sativa* L.), a constitute of family Gramineae ranks sixth in world cereal production. It is a dual purpose crop, becoming popular among the Indian farmers due to its high tonnage of nutritious and palatable fodder with a less requirement of water. It is grown in *rabi* season. However, its grain is used as baby food, breakfast food, and animal feed. It has gained importance due to the multi cut system, which ensures regular supply of fodder over a long period. The crop has been adopted well by the farmers because of its multicast nature and high yield of nutritious, palatable forage. Oat is predominantly utilized in cattle breeding and has occurred in the human diet for a long time, mainly oatmeal and rolled oats, but the positive physiological effects of oat products were recognized recently (Pirjo *et al*., 2003). It is considered to be a valuable component in agriculture as oat reduces disease pressure in cereal crop rotations and is therefore highly suited for sustaining, extensive production systems. The nutritive value of oat forage depends on maturity and varietal characteristics. As oat mature, yield increases and quality decreases. Research indicates that tall, late-maturing varieties produce the highest forage yields. In the multi cut management system, first cut is done at 65 to 75 days from the date of sowing and the second cut is taken at 50 percent flowering. Genotypic variation in yield exists. However, environmental factors also have a strong influence on both yield and quality and interactions between these factors (Browne *et al*., 2003; Doehlert and McMullen, 2000).

Oat both as forage and grain is a good source of protein, fibers, and minerals (Charalampopoulos *et al*., 2002; Demirbas 2005; Esposito *et al*., 2005). Additionally, oat is a source of several natural antioxidants such as tocopherols and phenolic acids and their derivatives, which are not present in other cereal grains (Bryngelsson *et al*., 2002; Liu *et al*., 2004; Mattila *et al*., 2005; Miller *et al*., 2000). All of these phenolic compounds possess potential health-promoting properties because of their antioxidant activities and membrane-modulating effects. In therapeutics, oat bran plays a vital role in reducing blood cholesterol level. Daily consumption of fiber present in oat bran assists in regulating gastrointestinal function. Moreover, β-glucans, which also exhibit an antioxidant capacity (Johansson *et al*., 2004; Lyly *et al*., 2004), are included in the soluble dietary fiber fractions of oats that participates in the glucose-regulation and causes a decrease in serum cholesterol levels in humans (Esposito *et al*., 2005; Johansson *et al*., 2000; Zwer 2004). The consumption of oat is, therefore, an essential component of the diet for hypercholesterolemia patients (Czerwinski *et al*., 2004).

The green fodder availability from single cut oat is less and short-lived, while multicast oat is advantageous in various ways like saving in cost of next crop, high yield in a shorter period and offers an opportunity of continuous supply of green forage. Such multicast varieties will find favor with the farmers being economical in production. Moreover, the quality of fodder of multi cut oat regarding protein, HCN content and digestibility has been reported to be improved

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because of its tenderness and succulent nature due to frequent cuttings. It is now well consider that Gramineae family plants have high regeneration potential and accumulate sucrose. Starch, pectin, and fructosan as nature of the principal carbohydrate storage form appear to be a characteristic of the regenerating plants (Hunter *et al*., 1970). Non- structural carbohydrates in roots are essential for regrowth of most perennial forage species (Sheaffer *et al*., 1998). Different species of oat vary in their regrowth. Regrowth of stem or shoot takes place if the first cut is removed by harvesting shoot at 10-15 cm above ground, however; information regarding the regrowth and biochemical constituents in these species is not available. Recent breeding efforts have resulted in the development of the high yielding varieties with better regeneration capacity.

To meet this shortage and to get a regular supply of good quality fodder for our livestock, it is required to increase either the area under fodder crops which is not possible due to more emphasis on grain and commercial crops in India or to develop "real multi cut" forage crop like bar seem, etc. Though, a few reports are available regarding the biochemical and nutritional aspects of regeneration in oats. Thus, this research aimed to evaluate the biochemical and nutritional aspects of oat genotypes responsible for its regrowth with the following objectives:

a) To determine the biochemical parameters responsible for regrowth of oats genotypes
b) To determine the nutritive value of grains of oats

II. Materials and Methods

a) Plant materials

The seeds of fourteen genotypes of oat viz. HFO 504 (*A. fatua*), HFO 58 (A. *barbata*), HFO 864 (A. brevis), HFO 498 (*A. longiglumis*), HFO 872 (A. sterilis), HFO 103 (*A.orientalis*), HFO 865 (*A. insularis*), HFO 870 (*A.vaviloviana*), HFO 873 (*A. murphy*), HFO 868 (*A.abyssinica*), Dunav-1, HJ8 (*A. sativa*), OS6 (*A. sativa*) and Kent (*A. sativa*) were obtained from the field of Forage Research Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar, India. The experiment followed a completely design was a randomized block design (RBD) with three replications.

b) Plant Harvesting

The plant samples have been collected at 50% flowering and 75 DAS for multi-cut management. All parts (shoot, stubble, roots) were dry in a hot air oven maintained at 70°C, ground in a Willey mill and stored in paper bags for the estimation of various chemical and biochemical constituents.

The parameters analyzed for multi-cut management were fresh weight and dry weight, crude protein, in vitro dry matter digestibility (IVDMD), total soluble sugars, fructans, phosphorus, carbon, nitrate nitrogen and for grains; β-carotene, sedimentation value, and starch.

c) Statistical analysis

The experimental data were analyzed by the application of RBD design using OPSTAT software available on CCSHAU web page (Sheoran, O.P.)

III. Results

a) Fresh and dry weight

Data reported in Table 1 reveals that the fresh and dry weight is greatly influenced by the stage of plant growth. The fourteen genotypes at two stages showed a wide variation for their fresh and dry weight. Among the genotypes at first cut, fresh weight ranged from 22.26 to 51.60g. Maximum was in HJ-8 (51.60 g) followed by HFO872 (44.84 g), and the lowest was in HFO870 (22.26 g). During harvesting of second cut, fresh weight ranged from 24.08 to 87.56g. The highest fresh weight was in HFO865 (87.56 g) followed by HFO873 (72.66 g), and the lowest was in HFO864 (24.08 g). During first cut, dry weight ranged from 3.17 to 10.14g. The highest was in Dunav-1 (10.14 g) followed by HFO873 (9.33 g), and the lowest was in HFO103 (3.17 g). During second cut, the dry weight of genotypes ranged from 3.87 to 18.21g. HFO865 contains maximum dry weight (16.66 g), and HFO868 contains the lowest (3.87 g). After harvesting at second cut, oat plants were left for regeneration, and it was found that regrowth does not takes place in HFO504, HFO870, HFO868, and OS-6. In rest of the genotypes, regrowth takes place. Further, the fresh and dry weight of samples at third cut was not in adequate quantity, so these parameters were not reported in Table 1.

Table 1: Fresh and dry weight of plant* (g/plant) of oat genotypes under multi-cut management

Genotypes	I cut		II cut	
	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
HFO 504	30.17	5.71	26.09	4.79
HFO58	31.58	5.53	35.72	6.31
HFO 864	34.87	8.25	24.08	5.44
HFO498	30.51	4.91	27.25	4.47
HFO 872	44.84	6.35	39.77	5.50

HFO103	27.28	3.17	45.59	5.22
HFO 865	37.79	6.84	87.56	18.21
HFO870	22.26	3.77	43.11	7.58
HFO873	40.55	9.33	72.66	16.66
HFO868	38.83	8.62	24.67	3.87
Dunav-1	41.45	10.14	35.07	7.03
HJ-8	51.60	5.88	47.47	5.50
OS 6	34.77	4.78	32.83	4.53
Kent	43.88	5.89	45.58	6.25
SE(m)	0.39	0.07	0.10	0.03
C. D. (5%)	1.20	0.23	0.33	0.12

*Plant = Including shoot + stubble + root

b) Crude protein

Data presented in Table 2, showed that at the first cut, crude protein in shoot varied from 10.20 to 14.68 percent. The highest was in Kent (14.68 %), and the lowest was in HFO103 (10.20 %). In the shoot of second cut genotypes, it varied from 11.63 to 16.35 percent. The maximum crude protein was in OS-6 (16.35 %), and the minimum was in HFO103 (11.63 %). Crude protein in the shoot of the third cut genotypes ranged from 6.59 to 9.79 percent. The highest was in HFO58 (9.79 %), and the lowest was in HFO865 (6.59 %). Crude protein in the stubble of first cut genotypes varied from 11.86 to 16.63 percent (Table 2). HFO870 found with highest content (16.63 %), and HFO504 had the lowest (11.86 %). In the stubble of second cut samples, crude protein ranged from 12.82 to 18.67 percent. The highest was in HFO870 (18.67 %), and the lowest was in HFO504 (12.82 %). In samples of the third cut stubble, it ranged from 7.32 to 10.51 percent. The maximum was in Kent (10.51 %), and the minimum was in HFO58 (7.32 %). In roots of the first cut samples, it ranged from 5.30 to 6.79 percent (Table 2). HFO865 had the highest crude protein (6.79 %), and Kent had the lowest content (5.30 %). Crude protein content in roots of the second cut genotypes ranged from 6.17 to 8.37 percent. The maximum crude protein was in OS-6 (8.37 %), and the minimum was in Kent (6.17 %). Crude protein in roots of the third cut varied from 7.16 to 9.58 percent. The highest crude protein was observed in HFO873 (9.58 %), and the lowest was in HFO872 (7.16 %).

Table 2: Crude protein (%dry weight basis) in different parts (shoot, stubble, and roots) of oat genotypes under multi-cut management system

Genotypes	I cut			II cut			III cut		
	Shoot	Stubble	Root	Shoot	Stubble	Root	Shoot	Stubble	Root
HFO 504	12.06	11.86	5.37	12.59	12.82	6.60	n.r.	n.r.	n.r.
HFO58	12.54	13.32	6.41	13.08	14.54	6.85	9.79	7.32	7.39
HFO 864	12.20	14.45	6.63	12.89	16.29	7.14	9.38	8.80	9.46
HFO498	13.82	15.87	5.81	14.53	16.01	6.45	7.61	8.78	8.60
HFO 872	14.52	15.52	6.59	15.58	16.88	7.26	7.13	9.59	7.16
HFO103	10.20	13.79	6.34	11.63	14.37	7.54	8.16	8.50	8.26
HFO 865	11.60	13.28	6.79	12.63	15.57	7.55	6.59	9.60	9.42
HFO870	12.63	16.63	6.28	13.42	18.67	6.88	n.r.	n.r.	n.r.
HFO873	13.22	14.33	6.58	14.63	16.61	7.37	8.35	10.32	9.58
HFO868	14.39	15.21	6.69	16.12	17.74	7.20	n.r	n.r	n.r
Dunav-1	11.51	14.58	6.36	12.39	16.52	7.37	9.17	10.12	8.36
HJ-8	14.43	15.63	5.77	12.54	16.50	6.46	8.48	9.10	8.14
OS 6	12.33	13.14	6.41	16.35	14.68	8.37	n.r.	n.r.	n.r.
Kent	14.68	14.29	5.30	15.67	16.41	6.17	8.11	10.51	8.20
SE(m)	0.29	0.20	0.20	0.26	0.28	0.17	0.29	0.23	0.14
C. D. (5%)	0.89	0.64	0.62	0.80	0.87	0.55	0.95	0.77	0.45

*n.r. – not regenerated

c) IVDMD

Data presented in Table 3 showed that IVDMD (percent dry weight basis) of different multi-cut genotypes did not show any regular trend. In shoot of first cut samples, it varied from 58.65 to 80.60 percent. HFO498 contains highest IVDMD (80.60 %), and Kent contains the lowest (58.56 %). It ranged from 59.45 to 83.35 percent in the shoot of second cut genotypes. HFO872 has maximum percent (83.35 %), and the minimum was in Kent (59.45 %). In the stubble of first cut samples, it varied from 55.40 to75.30 percent (Table 3). The highest was in HFO58 (75.30 %), and the lowest was in HFO504 (55.40 %). It varied from 54.55 to 74.15 percent in the stubble of second cut genotypes. HFO504 had the maximum IVDMD percent (74.15 %) and Kent had minimum (54.55 %).

Table 3: In-vitro dry matter digestibility (IVDMD %) and Nitrate Nitrogen content (µg/g) in different parts (shoot, stubble) of oat genotypes under multi-cut management system

Genotypes	IVDMD						Nitrate Nitrogen					
	I cut		II cut		III cut		I cut		II cut		III cut	
	Shoot	Stubble	Shoot	Stubble	Shoot	Stubble	Shoot	Stubble	Shoot	Stubble	Shoot	Stubble
HFO 504	71.9	55.4	78.05	74.15	n.r.	n.r.	25.5	22.5	23.5	20.5	n.r.	n.r.
HFO58	70.5	75.3	73.35	66.55	58.95	69.4	27.5	24.5	21.94	19.5	18.5	17.5
HFO 864	79.35	60.1	81.5	68.8	63.3	53.4	24.92	24.5	22.5	20.5	20.91	18.5
HFO498	80.6	61.3	82.25	66.55	50.55	58.55	27.5	22.5	23.5	18.5	19.5	20.5
HFO 872	67.75	63.75	83.35	72.6	51	79.45	30.5	26.5	25.5	22.5	21.5	19.5
HFO103	78.25	63.4	79.35	60.15	55.4	56.1	28.5	25.5	24.5	22.5	21.5	17.5
HFO 865	73.25	65.7	82.7	71.45	62.65	72.5	33.62	25.5	26.5	20.5	20.5	17.5
HFO870	70.25	70.1	75.45	46.6	n.r.	n.r.	28.5	25.5	22	21.5	n.r.	n.r.
HFO873	75.25	68.15	78.7	73.35	50.15	59.35	25.5	24.5	20.5	21.5	19.5	18.5
HFO868	72.55	61.35	73.35	68.55	n.r.	n.r.	25.5	21.5	23.5	19.5	n.r.	n.r.
Dunav-1	75.9	74.55	75.5	71.55	68.5	59.75	21.67	26.5	19.5	22.5	20.41	19.5
HJ-8	73.7	66.55	73.35	65.3	63.4	57.4	28.5	30.5	23.5	26.5	18.5	22.5
OS 6	76.15	65.5	71.65	55.4	n.r.	n.r.	23.5	26.5	20.5	23.5	n.r.	n.r.
Kent	58.65	59.4	59.45	54.55	67.35	53.35	25.69	23.5	23.72	18.5	21.09	17.5
SE(m)	0.14	0.12	0.14	0.17	0.15	0.16	0.46	0.51	0.45	0.51	0.41	0.31
C. D. (5%)	0.43	0.38	0.45	0.52	0.5	0.51	1.42	1.58	1.41	1.58	1.35	1.02

*n.r.- not regenerated

d) Total soluble sugar

Data in Table 4 revealed that multi-cut genotypes exhibited the low content of total soluble sugars in their roots and stubbles than in the single cut genotypes. The content of total soluble sugars in first cut stubble, varied from 2.92 to 5.79 percent. In the second cut stubble, it ranged from 2.31 to 3.31 percent. It ranged from 1.89 to 2.75 percent in the stubble of third cut genotypes. In the case of roots, it ranged from 2.37 to 4.40 percent in first cut samples of various genotypes. In second cut samples, it ranged from 1.52 to 3.52 percent. It varied from 0.91 to 2.26 percent in roots of third cut genotypes. In all cases, the highest total soluble sugar was in Dunav-1, and HJ-8 has the lowest.

e) Fructans Content

Fructans content in stubble of first cut samples, ranged from 0.05 to 0.22 per cent (Table 4). The highest was in HFO872 and HJ-8 (0.22 %), and the lowest was in HFO868 (0.05 %). In the stubble of second cut samples, it varied from 0.01 to 0.16 per cent. The maximum content was in HJ-8 (0.16 %), and the minimum was in HFO868 (0.01 %). In stubble of the third cut samples, it ranged from 0.02 to 0.13 percent. The highest was in HJ-8 (0.13 %), and Dunav-1 was had the lowest fructans content (0.02 %). In first cut samples of roots, it ranged from 0.07 to 0.82 per cent. The highest fructans content was in HJ-8 (0.82 %), and the minimum content (0.07 %) was recorded in four genotypes (HFO864, HFO504, HFO870 and OS6). In roots of second cut samples, it varied from 0.05 to 0.08 per cent. Three genotypes (HJ-8, HFO865 and HFO872) exhibited the highest content of fructans (0.08 %), and the lowest was in HFO864 and OS-6 (0.05 %). In roots of the third cut genotypes, it ranged from 0.03 to 0.08 per cent. The highest was in HJ-8 (0.08 %), and the lowest was in HFO864 (0.03 %).

Table 4: Non-structural carbohydrates (%dry weight basis) in different parts (shoot, stubble) of oat genotypes under Multi-cut management system

Genotypes	Total soluble sugar						Fructan					
	I cut		II cut		III cut		I cut		II cut		III cut	
	Stubble	Root	Stubble	Root	Stubble	Root	Stubble	Root	Stubble	Root	Stubble	Root
HFO 504	3.51	2.39	2.39	2.87	n.r.	n.r.	0.12	0.07	0.12	0.07	n.r.	n.r.
HFO58	3.6	4.25	3.24	2.2	2.48	1.51	0.09	0.08	0.09	0.06	0.09	0.05
HFO 864	3.55	3.62	3.24	1.73	2.28	1.6	0.11	0.07	0.11	0.05	0.03	0.03
HFO498	3.42	3.83	2.61	2.27	2.25	1.88	0.15	0.08	0.13	0.06	0.09	0.05
HFO 872	3.32	3.1	2.46	2.14	2.07	1.24	0.22	0.09	0.12	0.08	0.12	0.07
HFO103	3.53	3.6	3.29	2.43	2.62	1.61	0.08	0.08	0.03	0.07	0.1	0.06
HFO 865	3.31	2.98	2.47	2.17	2.27	1.31	0.19	0.74	0.13	0.08	0.11	0.06
HFO870	3.42	3.7	2.83	2.4	n.r.	n.r.	0.15	0.07	0.07	0.07	n.r.	n.r.
HFO873	3.2	3.58	2.53	2.37	2.03	1.27	0.18	0.09	0.11	0.07	0.1	0.06
HFO868	3.32	2.52	2.79	2.13	n.r.	n.r.	0.05	0.1	0.01	0.06	n.r.	n.r.

Dunav-1	5.79	4.4	3.31	3.52	2.75	2.26	0.15	0.09	0.08	0.07	0.02	0.05
HJ-8	2.92	2.37	2.31	1.52	1.89	0.91	0.22	0.82	0.16	0.08	0.13	0.08
OS 6	3.48	3.21	3.17	2.44	n.r.	n.r.	0.08	0.07	0.02	0.05	n.r.	n.r.
Kent	4.24	2.77	2.59	2.62	2.1	1.8	0.13	0.1	0.07	0.06	0.04	0.04
SE(m)	0.14	0.1	0.11	0.06	0.08	0.03	0.003	0.01	0.002	0.001	0.002	0.002
C. D. (5%)	0.44	0.3	0.36	0.19	0.28	0.12	0.008	0.04	0.005	0.004	0.007	0.005

*n.r.- not regenerated

f) Phosphorus

Data presented in Table 5 showed that phosphorus content varied from 0.48 to 0.63 mg/g in the shoot of first cut samples of various genotypes. HJ-8, HFO865 and HFO872 had the highest phosphorus content and HFO864 (0.52 mg/g) had the lowest. During second cut, it varied from 0.73 to 0.97 mg/g in shoot samples of various genotypes. The maximum content was in HJ-8 (0.97 mg/g), and the minimum was found in HFO498 (0.73 mg/g). The phosphorus content in the shoot of third cut genotypes ranged from 0.95 to 1.23 mg/g. The highest was in HFO873 (1.23 mg/g), and the lowest was in HFO864 (0.95 mg/g).

In stubble, first cut samples of oat genotypes varied from 0.39 to 0.67 mg/g (Table 5). HJ-8 found with the highest content (0.67 mg/g), and OS-6 had the lowest phosphorus content (0.39 mg/g). In the stubble of second cut samples, phosphorus content ranged from 0.45 to 1.00 mg/g. The highest content of phosphorus was in HJ-8, HFO865 and HFO872 (1.00 mg/g), and the lowest was in OS-6 (0.45 mg/g). During the third cut, phosphorus content varied from 1.13 to 1.60 mg/g. The maximum was in HJ-8 (1.60 mg/g), and the minimum was reported in Kent (1.13 mg/g) while OS-6, HFO870, and HFO504 do not show any regeneration.

In roots of first cut samples, phosphorus content varied from 0.69 to 0.87 mg/g (Table 5). HJ-8 had the highest content (0.87 mg/g), and HFO864 found with lowest content (0.69 mg/g). Phosphorus content in roots of second cut genotypes ranged from 0.90 to 0.96 µg/g. HJ-8 (0.96 µg/g) had the maximum and HFO864 (0.90 µg/g) had the minimum. Phosphorus content in roots of the third cut varied from 1.08 to 1.40 mg/g. HJ-8 (1.40 µg/g) had the highest content and HFO58 (1.08 µg/g) had the lowest content.

Table 5: Phosphorus content (mg/g) in different parts (shoot, stubble, and roots) of oat genotypes under multi-cut management system

Genotypes	I cut			II cut			III cut		
	Shoot	Stubble	Root	Shoot	Stubble	Root	Shoot	Stubble	Root
HFO 504	0.53	0.59	0.74	0.94	0.93	0.91	n.r.	n.r.	n.r.
HFO58	0.57	0.6	0.74	0.87	0.96	0.94	1.09	1.24	1.08
HFO 864	0.48	0.57	0.69	0.89	0.92	0.9	0.95	1.42	1.19
HFO498	0.53	0.54	0.77	0.73	0.96	0.91	1.18	1.14	1.12
HFO 872	0.63	0.59	0.82	0.92	1	0.95	1.19	1.35	1.3
HFO103	0.54	0.61	0.84	0.86	0.93	0.93	1.1	1.27	1.25
HFO 865	0.63	0.66	0.85	0.93	1	0.95	1.2	1.38	1.32
HFO870	0.56	0.6	0.81	0.85	0.9	0.94	n.r.	n.r.	n.r.
HFO873	0.52	0.65	0.85	0.93	0.97	0.95	1.23	1.56	1.35
HFO868	0.44	0.63	0.75	0.86	0.95	0.95	n.r.	n.r.	n.r.
Dunav-1	0.57	0.57	0.85	0.92	0.93	0.94	1.06	1.24	1.15
HJ-8	0.63	0.67	0.87	0.97	1	0.96	1.21	1.6	1.4
OS 6	0.56	0.39	0.85	0.85	0.45	0.92	n.r.	n.r.	n.r.
Kent	0.57	0.64	0.85	0.81	0.96	0.93	1.09	1.13	1.15
SE(m)	0.01	0.01	0.01	0.01	0.12	0.01	0.03	0.04	0.02
C. D. (5%)	0.05	0.04	0.05	0.05	N/A	N/A	0.12	0.13	0.09

*n.r.- not regenerated

g) Nitrate Nitrogen

Nitrate nitrogen content also did not show any regular trend. In shoot of first cut samples varied from 21.67 to 33.62 µg/g (Table 3). HFO865 (33.62 µg/g) had the highest and Dunav-1 had the lowest (21.67 µg/g). Nitrate nitrogen content varied from 19.50 to 26.50 µg/g in the shoot of second cut genotypes. The maximum was in HFO865 (26.50 µg/g), and the minimum was in Dunav-1 (19.50 µg/g). In shoot of the third cut, nitrate nitrogen content ranged from 18.50 to 21.50 µg/g. HFO872 and HFO103 found with highest nitrate nitrogen content (21.50 µg/g), and lowest in HFO58 and HJ-8 (18.50 µg/g). The content of nitrate nitrogen in the stubble of first cut genotypes varied from 21.50 to 30.50 µg/g (Table 3). The highest nitrate nitrogen content was in genotype HJ-8 (30.50 µg/g), and lowest was in HFO868 (21.50 µg/g). Its content in the stubble of second cut genotypes ranged from 18.50 to 26.50 µg/g.

Maximum nitrate nitrogen content was in HJ-8 (26.50 µg/g), and the minimum was in HFO498 (18.50 µg/g). During third cut, nitrate nitrogen content in stubble ranged from 17.50 to 22.50 µg/g. Highest was in genotype HJ-8 (22.50 µg/g), and the lowest was in HFO58, HFO103, HFO865 and Kent (17.50 µg/g).

h) Carbon content

Data presented in Table 7 showed that carbon content in shoot samples at first cut varied from 25.75 to 36.74 percent. The highest was found in HFO870 (36.74 %), and the lowest was in HFO872 and HFO868 (25.75 %). In the shoot, of second cut samples, it varied from 26.37 to 36.74 percent. Maximum carbon content was in HJ-8 (36.74 %), and the minimum was in OS-6 (26.37 %). Carbon content in the shoot of third cut genotypes ranged from 18.04 to 38.67 percent. The highest was in HJ-8 and HFO864 (38.67 %), and the lowest was in HFO103 (18.04 %). Carbon content in the stubble of first cut samples varied from 31.27 to 39.57 percent (Table 10). HJ-8 found with the highest content (39.57 %), and Kent had the lowest carbon content (31.27 %). In the stubble of second cut samples, carbon content ranged from 35.55 to 42.46 percent. The highest was in HJ-8 (42.46 %), and the lowest was in HFO498 (35.55 %). In the stubble of the third cut samples, carbon content varied from 41.45 to 46.63 percent. Maximum was in HJ-8 (46.63 %), and the minimum was in HFO58 (41.45 %).

In roots of first cut samples, carbon content varied from 20.17 to 28.32 percent (Table 7). HJ-8 had the highest carbon content (28.32 %), and HFO498 and Kent had the lowest content (20.17 %). Carbon content in roots of second cut genotypes ranged from 25.64 to 32.83 percent. Maximum carbon content was in HJ-8 (32.83 %), and the minimum was in HFO498 (25.64 %). Carbon content in roots of the third cut varied from 30.61 to 36.86 percent. The highest carbon content was in HJ-8 (36.86 %), and the lowest was in HFO865 (30.61 %).

Table 7: Carbon content (%dry weight basis) in different parts (shoot, stubble, and roots) of oat genotypes under multi-cut management system

Genotypes	I cut			II cut			III cut		
	Shoot	Stubble	Root	Shoot	Stubble	Root	Shoot	Stubble	Root
HFO 504	31.42	35.75	23.45	34.87	37.59	29.68	n.r.	n.r.	n.r.
HFO58	27.65	32.04	26.56	33.03	38.93	28.8	34.99	41.45	33.54
HFO 864	29.37	35.74	21.83	31.28	37.45	27.46	38.67	43.25	32.62
HFO498	29.47	31.48	20.17	29.7	35.55	25.64	33.03	45.24	34.6
HFO 872	25.75	37.71	23.83	36.73	39.46	30.82	31.48	43.88	31.81
HFO103	27.59	33.71	23.83	29.69	41.95	31.18	18.04	43.78	34.55
HFO 865	25.74	35.71	27.33	36.73	38.45	27.46	36.74	41.81	30.61
HFO870	36.74	39.56	21.84	31.48	39.55	27.7	n.r.	n.r.	n.r.
HFO873	33.03	33.73	23.72	34.82	37.9	27.45	33.04	44.77	31.49
HFO868	25.75	37.55	25.61	29.59	39.69	31.83	n.r.	n.r.	n.r.
Dunav-1	31.15	35.75	21.86	27.63	38.53	28.64	31.28	41.51	31.34
HJ-8	34.84	39.57	28.32	36.74	42.46	32.83	38.67	46.63	36.86
OS 6	27.66	37.59	25.65	26.37	41.85	31.12	n.r.	n.r.	n.r.
Kent	27.66	31.27	20.17	31.29	37.55	32.74	34.67	43.8	36.46
SE(m)	0.07	0.12	0.11	0.19	0.09	0.07	4.77	0.07	0.11
C. D. (5%)	0.22	0.38	0.34	0.59	0.3	0.22	N/A	0.23	0.37

*n.r.- not regenerated

i) Biochemical Parameters of Oat Grain

i. *Starch*

Data presented in Table 8 showed that starch content in grains varied from 47.95 to 59.44 percent. Maximum starch content was in HFO870 (59.44 %) followed by HFO103 (57.65 %), and the minimum was in HFO498 (47.95 %).

ii. *Crude protein*

In grains, crude protein content ranged from 7.75 to 18.76 percent (Table 8). Dunav-1 had the highest crude protein content (18.76 %) followed by HFO868 (18.15 %), and the lowest in HFO873 (7.75 %).

iii. *Sedimentation value*

Sedimentation value of grains, varied from 16.50 to 30.50 ml (Table 8). Maximum was in HFO865 (30.50 ml) followed by HFO873 (28.50 ml), and the minimum was in Kent (16.50 ml).

iv. *β-carotene*

In grains, β-carotene content ranged from 68.17 to 110.31 µg/g (Table 8). The highest content was in HJ-8 and Kent (110.31 µg/g) followed by HFO864 (107.49 µg/g), and the lowest was in OS-6 (µg/g).

Table 8: Biochemical parameters of oat grains

Genotypes	Starch (%)	Crude Protein (%)	Sedimentation Value (ml)	β-carotene (µg/g)
HFO 504	52.76	12.03	18	93.83
HFO58	56.54	8.77	17	97.72
HFO 864	51.44	12.03	25.5	107.49
HFO498	47.95	12.24	17	84.06
HFO 872	51.75	11.42	17.5	77.23
HFO103	57.65	9.58	17	91.36
HFO 865	51.58	12.03	30.5	69.93
HFO870	59.44	16.73	26.5	91.36
HFO873	54.6	7.75	28.5	96.31
HFO868	53.36	18.15	22	79.47
Dunav-1	56.32	18.76	23	81.82
HJ-8	52.23	11.01	22.5	110.31
OS 6	53.31	13.46	19.5	68.17
Kent	55.48	9.58	16.5	110.31
SE(m)	0.16	0.8	0.86	4.29
C. D. (5%)	0.51	2.47	2.66	13.24

IV. Discussion

The fresh and dry weight of plant (includes shoot + stubble + root) did not show any regular trend. HFO865 and HFO873 show a significant increase in weight. Similar observations were recorded by Nawaz *et al*. (2004). Increase in the photosynthetic activity is directly related to the greater leaf area; as a result, it will increase the capacity to storethe products of photosynthesis, which ultimately lead to higher yield of oat cultivars (Amanullah *et al*., 2004)

Crude protein content was found high in the shoot as compared to stubble and root. The leaves contain the higher amount of protein and cell contents and lower amount of structural carbohydrates in comparison to stem. Moreover, crude protein was observed to be decreasing progressively with plant age. Similar results were observed by Singh et al. (1973) and Boonman (1997) who designated oat as a nutritious fodder and observed decrease in crude protein and cell contents with the advancement of maturity. Therefore, because of the decrease in protein content with age, Christensen (1993) suggested that harvesting of oat forage should be done at an early-dough stage for maximum nutritive value as it may lose feeding value with advancing maturity.

The stage of maturity is also found to influence the nutritive value of forages. IVDMD percent first increased progressively from the first cut to the second cut but decreased at the third cut. Further, the IVDMD percent reduced in the stubble as compared to the shoot (Table 3). It is due to the high NDF and ADF content in the stubble as compared to the shoot. Furthermore, the IVDMD percent was inversely related to the cell wall constituents NDF, ADF, cellulose, lignin, silica, and hemicellulose, due to which animals are not able to eat the required quantity of fodder. In vitro dry matter digestibility which takes in to account all the known and unknown factors chiefly dependent upon the concentration of cellulose and hemicelluloses, which in turn is influenced by the degree of lignifications and silicification (Van Soest and Jones, 1968). Lignin and silica contents have also been found to reduce the IVDMD (Arora *et al*., 1977). Dost *et al*. (1994) also observed that fodder yield and quality was influenced by plant age, the crude protein content and in vitro dry matter digestibility decreasing as the forage crop matures.

Nitrate-nitrogen decreased progressively with increased plant maturity. Harada *et al*. (2002) also studied changes in growth and nitrate nitrogen concentration of oat and sorghum under heavy nitrogen fertilization and found a dramatic decrease in nitrate-nitrogen concentration of oat with increasing dry matter content, while no change for fresh content. This decrease in nitrate-nitrogen concentration is related with the increase in dry matter content of oat. However, Wilman and Wright (1986) reported that increasing the interval between harvests tended to increase the amount of nitrate-N in the herbage; however, this seemed due mainly to the average date of harvest being later in the year with the longer intervals. The concentration of nitrate-N in herbage increased from June to September.

a) Biochemical parameters responsible for regrowth of oat genotypes

In the present investigation, phosphorus and fructans content was high in multi-cut genotype (HJ-8) as compared to single cut genotype (OS6). In stubble, phosphorus and fructans content was high as compared to roots while total soluble sugar content was low in multi-cut genotypes, as compared to single cut genotypes. Since phosphorus is a component of several biological compounds and involve with cell division, and

cell elongation and its presence in high amounts in roots and stubbles of multi-cut genotypes under study indicate that it may play a definite role in regeneration. Similar results are observed by Custodio et al. (2004), these authors were of the view that root initiation and growth are highly energy requiring processes that can occur only at the expense of available metabolic substrates, mainly sugars. Phosphorus is responsible for cell division and growth in the first four weeks, and eventually yield formation (Grant et al. 2001). Hunter et al. (1970) studied that Gramineae family plants have high regeneration potential and accumulate sucrose, starch, pectins, and fructans as the chief storage carbohydrate which appears to be characteristic of the regenerating plants. Pandey (1964) studied that phosphorous, a component of several biological compounds plays a crucial role in the synthesis of sugars. It also participates in energy consumption, transfer of genetic information and regulates the activity of enzymes and metabolic pathways (Maleszewshri et al., 2004). This study is supported by Kumar and Bhatnagar (1992). They reported the preponderance of amylase activity over acid and neutral invertases to provide hexoses for the stubble buds to sprout and non-structural carbohydrates concentration. Ground parts are found to be associated with regrowth and perenniality in rice (Turner et al. 1993).

b) Nutritive value of oat grains

In the present study, starch content varied from 56.54 to 59.44 percent (Table 8). Genotype HFO870 topping the list and HFO58 is on the bottom. Crude protein content in this investigation ranged from 7.75 to 18.76 percent. Dunav-1 was topping the list while HFO873 is on the bottom. Zarkadas et al. (1995) reported protein values of 10–12 percent in the whole oat grain. Arora et al. (1974) reported 10.94 to 14.00 percent protein and 51.00 to 59.00 percent starch content in grains of oat. Sedimentation value of grains, varied from 16.50 to 30.50 ml. Maximum was in HFO865 (30.50 ml) followed by HFO873 (28.50 ml), and the minimum was in Kent (16.50 ml). It indicates that flour quality of HFO865 is better than other genotypes. In grains, β-carotene content ranged from 68.17 to 110.31 µg/g. The highest content was in HJ-8 and Kent (110.31 µg/g) followed by HFO864 (107.49 µg/g) and the lowest was in OS-6 (68.17µg/g). β-carotene act as an antioxidant and is a source of Vitamin A. Results showed that genotypes HFO870, Dunav-1, HFO865 and HJ-8 as well as Kent are promising one for starch (59.44 %), crude protein content (18.76 %) sedimentation value (30.50 ml) and β-carotene content (110.31 µg/g).

V. Conclusion

Multicut oat is advantageous in various ways like saving in cost of next crop, high yield in a shorter period and offers an opportunity of continuous supply of green forage. Moreover, the quality of fodder of multi-cut oat has been reported to be improved because of tenderness and succulent nature of forage due to frequent cuttings. To meet the shortage and to get a regular supply of good quality fodder for livestock, it is required to develop "real multi-cut" forage crop. This study indicates that fructan, phosphorus and carbon content were playing a vital role in the regeneration of multi-cut genotype (*viz*. HJ8).

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