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Response of fodder oat (*Avena sativa* L.) varieties to irrigation and fertilizer gradient

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Abstract
An experiment was conducted during 2010-2012 at Jhansi (Uttar Pradesh) to study the performance of fodder oat (*Avena sativa* L.) varieties under varied irrigation and fertilizer rates. The experiment was consisted of 18 treatment combinations, *viz*., 2 fodder oat variety (JHO 99-1 and JHO 99-2), 3 irrigation schedules (0.8, 1.0 and 1.2 IW/CPE) and 3 fertilizer levels (75, 100 and 125% of recommended dose of fertilizer-RDF). Result showed that varieties of oat did not differ significantly in relation to growth, yield and water-use efficiency, but JHO 99-2 accumulated higher crude protein than JHO 99-1. The significant response of growth, dry fodder yield and nutrient uptake to irrigation was observed upto 1.0 IW/CPE and it increased green and dry fodder yields by 11.8 and 7.3%, respectively over 0.8 IW/CPE. Likewise application of 125% of RDF increased green and dry fodder yields by 17.7 and 10.4%, respectively. Water-use efficiency was increased with fertilizer and vice-versa with irrigation intensity. Apparent nutrient (N, P and K) balances were decreased with irrigation and increased with graded fertilizer application except potassium. Nitrogen and potassium apparent balances were negative. The maximum economic returns were obtained when crop was fertilized with 125% of RDF and irrigation scheduled at 1.0 IW/CPE.

Keywords: Fertilizer, Fodder yield, Irrigation scheduling, Nutrient balance, Oat varieties, Water-use efficiency

Introduction
Oat (*Avena sativa* L.) is a fast growing and high yielding winter fodder crop. It is highly palatable, nutritious and energy rich fodder and can be fed to animals either in the form of green fodder or after converting into good quality hay/silage (Dar *et al*., 2007). Besides, it possesses high regeneration ability. Thus it requires a large quantity of fertilizers for enhancing production of quality herbage (Singh and Dubey, 2007). Many varieties of oat have been developed which differ in input responses. Nutrient and water are the major inputs that influence the fodder yield and quality. High dose of chemical fertilizers to fodder crop can raise the possibilities of nitrate hazards to livestock as well as ground water pollution. At the same time, low priority to fodder crops, rise in fertilizer prices and their short supply at peak growing period limits the use of chemical fertilizers in forages. Water is an important input for realizing high crop productivity, however, it is becoming the most limiting factor for crop production in most of the parts of India due to less recharging of ground water. Therefore, it is essential to improve irrigation water productivity and decrease irrigation demand while maintaining the crop productivity. Limited quantity of water available for irrigation calls for scheduling of irrigation to improve water productivity of oat. Prihar *et al*. (1974) suggested a modified meteorological approach based on the ratio between irrigation water (IW) and cumulative pan evaporation (CPE) as a practical guide for scheduling irrigation to crop. Oat irrigated at 0.8 and 1.0 IW/CPE ratios gave higher green fodder yield than its lower level (Lal and Shukla, 1987). The agronomic information regarding suitability of varieties and their responses to nutrient and water is lacking in central part of India. Hence the present investigation was undertaken to identify nutrient and moisture regimes for oat varieties.

Materials and Methods
Experimental site and designing: Field experiments (2010-12) were carried out at Central Research Farm of ICAR-Indian Grassland and Fodder Research Institute (ICAR-IGFRI) Jhansi, India (25^0 27’ N latitude, 78^0 33’ E longitude and 270 m above mean sea level). The area has a continental monsoon climate with long term average annual rainfall of 908 mm received mostly during June to September. The total rainfall received during crop growing season was 4 and 46 mm in 2010–11 and 2011–12, respectively. The study area was characterized by semi-arid climate, with extreme temperature during summer (43 to 46 ^{0}C) and winter (as low as 2 ^{0}C). The soil was gravelly sandy loam in texture with 6.8 pH and

0.21 dS/m electrical conductivity. It recorded 4.30 g/kg of organic carbon, 192.7 kg/ha of available N, 14.3 kg/ha of available P and 293.6 kg/ha of available K in the top 15 cm soil at start of experiment.

The experiment was laid out in split-plot design with 3 replications, comprising 2 varieties of oat (JHO 99-1 and JHO 99-2) and 3 irrigation schedules (0.8, 1.0 and 1.2 IW/CPE) in main-plots and 3 fertilizer levels (75, 100 and 125% RDF) in sub-plots. The recommended dose of fertilizer (RDF) for oat was 90–40–40 kg N–P_2O_5–K_2O/ha. Entire phosphorus (P_2O_5) and potassium (K_2O) and half dose of nitrogen (N) were applied as basal at the time of sowing, whereas remaining nitrogen was applied during first irrigation. Oat was sown in lines 25 cm apart on 30 and 17 November in 2010 and 2011, respectively using a seed rate of 100 kg/ha. A buffer channel of 1.0 m width was provided on side of plots to avoid seepage effects. At each irrigation, 50 mm depth of water was applied as per treatment on the basis of evaporation from USWB Open Pan Evaporimeter located in Meteorological Observatory, ICAR-IGFRI, Jhansi.

Methods of analysis: Oat crop was harvested at 50% flowering stage and weighed for green fodder yield. Random chopped samples of green fodder was sun dried and placed in the oven at 65 ^{0}C for 72 hours to estimate dry matter percentage and then it was multiplied with respective green fodder yield to calculate dry fodder yield. Oven dried samples were kept for nutrient content. N concentration in plant samples was estimated by modified Kjeldhal method, P concentration by Vanado-molybdo-phosphoric yellow colour method and K concentration by Flame Photometer method as per the procedure described by Jackson (1973) and uptake was obtained as product of concentration and dry fodder yield. Crude protein content expressed as N × 6.25 and crude protein yield was calculated by multiplying crude protein content with dry fodder yield. Water-use efficiency (WUE) was calculated using following formula-

Water use efficiency (kg DM/ha-mm) =

$$\frac{\text{Dry fodder yield of oat (kg/ha)}}{\text{Consumptive use (mm)}}$$

Consumptive use of water was worked out by using the formula suggested by Dastane (1972). Apparent nutrient (N, P and K) balance was estimated as the difference between nutrient added through fertilizers and nutrient removed by crop as suggested by Liu *et al*. (2003). The economics of the treatment was calculated based on prevailing prices of input and output. Benefit: cost ratio was calculated by dividing net return with cost of cultivation. The package SAS version 9.3 (SAS Institute Inc, Cary, NC) was used to analyses the data.

Results and Discussion

Growth and yield: Oat varieties were statistically similar in producing tillers and plant of identical height, while plants with higher leaf: stem ratio were recorded in JHO 99-2 (Table 1). Significantly taller plants (147.1 cm) with more number of tillers (77) and leaf: stem ratio (0.54) were observed in the plot when irrigation was scheduled at 1.0 IW/CPE. Further increase the intensity of irrigation failed to exert any significant effect on these parameters. Similarly, these parameters were responded to fertilizers upto 100% of RDF level except leaf: stem ratio.

Green as well as dry fodder yield of oat were influenced significantly with irrigation and fertilizer levels (Table 1). Both the varieties of oat were at par in producing fodder yield. Similar result was also reported by Palsaniya *et al.* (2015) at the same location. As irrigation intensity was increased, the dry and green fodder yields were increased. The significant response of green and dry fodder yields to irrigation were found upto 1.2 and 1.0 IW/CPE, respectively. The magnitudes of increase in green and dry fodder yields under 1.2 IW/CPE were 17.7 and 10.4%, respectively over 0.8 IW/CPE. Likewise, graded application of fertilizers from 75 to 125% of RDF improved green and dry fodder yields of oat by 17.7 and 18.4%, respectively. The improvement in the fodder yield could be attributed to improved growth parameters *viz*., plant height and tiller number. These results were in conformity with those of Assefa and Ledin (2001) and Jehangir *et al*. (2013).

Fertilizer application amplified the irrigation effect and vice versa (Fig. 1). The maximum green fodder yield (48.48 t/ha) was recorded under 125% of RDF coupled with irrigation at 1.2 IW/CPE. Furthermore, the yield response to fertilizer was lower under low irrigation intensity. This confirmed the positive effect of adequate soil water on nutrients availability and the capacity that the plant had for a simultaneous uptake of water and nutrients leading to their more effective use when both were at a satisfactory level. It indicated that as application of fertilizers increased the requirement of irrigation water also increased. Mandal *et al.* (2006) reported a greater yield response with fertilizer application under adequate soil water conditions and a lower one under deficit water conditions in Central India.

Table 1. Effect of irrigation schedules and fertilizer levels on growth, fodder yield and water use efficiency of oat varieties (pooled data of 2 years)

Treatments	Plant height (cm)	Tillers/metre row length	Leaf:stem ratio	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	WUE (kg DM/ ha-mm)
Variety						
JHO 99-1	144.7	72	0.51	40.29	6.83	39.3
JHO 99-2	147.2	75	0.55	41.59	7.04	40.3
SEm±	1.6	1.69	0.01	0.42	0.08	0.5
CD (*P*<0.05)	NS	NS	0.02	NS	NS	NS
Irrigation Schedule						
0.8 IW/CPE	140.7	64	0.49	37.27	6.55	42.4
1.0 IW/CPE	147.1	77	0.54	41.68	7.03	40.1
1.2 IW/CPE	149.9	79	0.56	43.88	7.23	36.8
SEm±	2.0	2.07	0.01	0.52	0.10	0.6
CD (*P*<0.05)	6.2	6.52	0.03	1.62	0.31	1.8
Fertilizer level						
75 % RDF	140.0	67	0.51	37.33	6.30	36.9
100 % RDF	147.4	76	0.53	41.53	7.04	40.4
125 % RDF	150.4	78	0.55	43.95	7.46	42.0
SEm±	1.8	1.79	0.01	0.38	0.08	0.5
CD (*P*<0.05)	5.3	5.21	NS	1.09	0.23	1.6

RDF: Recommended dose of fertilizer; WUE: Water-use efficiency; DM: Dry matter

Water-use efficiency: The water-use efficiency (WUE) was decreased significantly with the increase of irrigation intensity (Table 1). The highest water-use efficiency (42.4 kg DM/ha-mm) was attained when irrigation was scheduled at 0.8 IW/CPE and lowest under 1.2 IW/CPE. In contrast, water use efficiency was increased with fertilizer levels and maximum value (42.0 kg DM/ha-mm) was found in 125% of RDF. Ram *et al*. (2013) and Singh *et al*. (2015) also reported a decrease in WUE with an increase in irrigation levels due to proportionately diminishing rate of increase in dry fodder yield with increase in evapotranspiration.

Nutrient uptake and apparent balance: Nitrogen uptake by fodder oat variety JHO 99-2 was 10.9 kg more in comparison to JHO 99-1 while P and K removal were statistically similar in both the varieties of oat (Table 2). Among the irrigation schedules, maximum uptake of N (108.4 kg/ha) and K (109.4 kg/ha) was recorded under 1.2 IW/CPE but at par with 1.0 IW/CPE. Phosphorus uptake was not influenced significantly with the irrigation schedules. Graded application of fertilizer significantly increased N, P and K uptake and maximum uptake of these nutrients were registered under 125% of RDF which was 32.3, 28.1 and 23.1% higher over 75% of RDF, respectively. The increase in nutrient uptake with irrigation and fertilizer levels might be due to higher nutrient content and fodder yield. Similar result was also reported by Jat *et al*. (2013).

Apparent N and K balance was found negative while P balance was positive under all the treatments except 75% of RDF (Fig. 2). More negative apparent N balance was observed in JHO 99-2 (–18.0 kg/ha) than JHO 99-1 (–7.1 kg/ha) variety of fodder oat. In general, apparent nutrient balance was decreased with increasing irrigation intensity and vice-versa with fertilizer levels except apparent K balance. It was decreased even with the application of fertilizers. Maximum apparent N and P balance were found under 125% of RDF which was 16.7 and 4.9 kg/ha higher over 75% of RDF, respectively. In contrast, higher apparent K balance was associated with 75% of RDF. The negative N and K apparent balance might be due to continuous crop mining of N and K coupled with inadequate replenishment (Rafique *et al*., 2012). More negative N and K apparent balance with high irrigation intensity and fertilizer dose was probably due to major increase in crop biomass, leading to export of greater amount of nutrients from soil.

Crude protein: Crude protein (CP) yield was higher in JHO 99-2 (675 kg/ha) in comparison to JHO 99-1 (607

Table 2. Effect of irrigation schedules and fertilizer levels on nutrient uptake, crude protein and economics of oat varieties (pooled data of 2 years)

Treatments	Nutrient uptake (kg/ha)			CP content (%)	CP yield (kg/ha)	Net returns (ha^{-1})	Benefit : cost
	N	P	K				
Variety							
JHO 99-1	97.1	15.8	103.4	8.92	607	16505	1.04
JHO 99-2	108.0	16.1	106.6	9.58	675	17549	1.11
SEm±	2.00	0.27	1.05	0.11	12.48		
CD (*P*=0.05)	6.29	NS	NS	0.34	39.31		
Irrigation Schedule							
0.8 IW/CPE	95.7	15.3	99.5	9.14	598	14347	0.92
1.0 IW/CPE	103.7	16.4	106.1	9.24	648	17878	1.15
1.2 IW/CPE	108.4	16.2	109.4	9.38	677	18855	1.15
SEm±	2.44	0.33	1.28	0.13	15.28		
CD (*P*=0.05)	7.70	NS	4.04	NS	48.14		
Fertilizer level							
75 % RDF	87.5	13.9	93.5	8.71	547	14798	0.98
100 % RDF	104.3	16.2	106.4	9.31	652	17502	1.10
125 % RDF	115.8	17.8	115.1	9.74	724	18780	1.13
SEm±	1.52	0.29	1.41	0.11	9.50		
CD (*P*=0.05)	4.44	0.84	4.12	0.33	27.73		

RDF: Recommended dose of fertilizer; CP: Crude protein

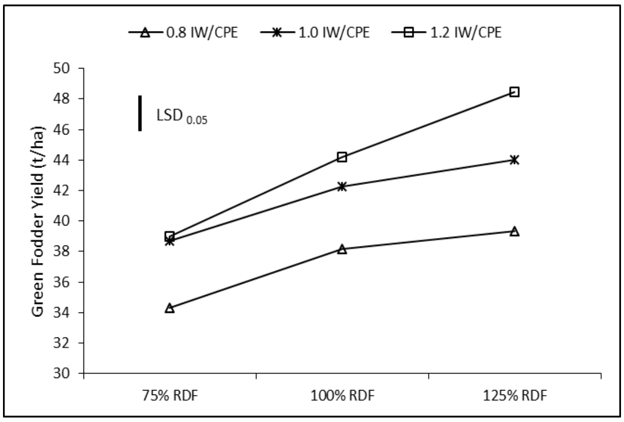

Fig 1. Interaction effect of irrigation schedules and fertilizer levels on green fodder yield in oat

kg/ha). Among the irrigation schedules, 1.2 IW/CPE produced 13.2% higher CP yield over 0.8 IW/CPE, but it was statistically at par with 1.0 IW/CPE. The increase in crude protein yield with increasing IW/CPE ratio was due to favourable soil moisture for uptake of native and applied nutrients. Gangaiah (2005) observed a similar increase in crude protein yield due to increase in levels of irrigation.

Successive increase in the fertilizers level also improved CP content and CP yield (Table 2). Furthermore, application of 125% of RDF increased CP yield by 32.3% and 11.0% over 75% and 100% of RDF, respectively. The improvement in crude protein content with increasing fertilizer levels was probably due to enhancement in amino acid formation. Higher crude protein yield mainly owed to increase in fodder yield as well as N content under improved nutrition. Higher CP content and CP yield with increasing fertilizer levels was also observed in pearl millet (Choudhary and Prabhu, 2014).

Economics: Economic analysis showed that the highest net returns (18855 Rs/ha) and B:C ratio (1.15) was realized when irrigation was scheduled at 1.2 IW/CPE which was very close to 1.0 IW/CPE (Table 2). As irrigation intensity was increased from 0.8 to 1.0 and 1.0 to 1.2 IW/CPE, the increase in net returns were 3531 and 977 /ha, respectively. Similarly, net returns and B:C ratio were increased with graded application of fertilizers and found maximum under 125% of RDF. The higher net returns and B:C ratio might be due to more returns from higher yield as compared to cost involved under these treatments.

Conclusion

It was concluded that 125% of recommended dose of fertilizer application (112-50-50 kg N-P_2O_5-K_2O/ha) and irrigation scheduled at 1.0 IW/CPE in fodder oat varieties increased fodder productivity, profitability and nutrient

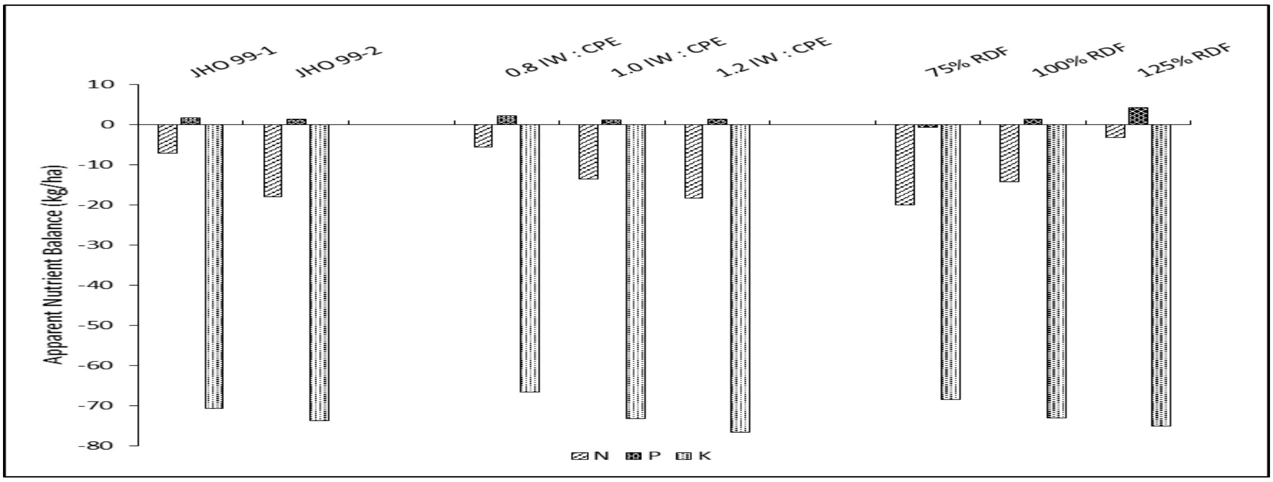

Fig 2. Effect of irrigation scheduling and fertilizer levels in different oat varieties on apparent nutrient balance

uptake, but decreased water-use efficiency and apparent nutrient balances.

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