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Article

Impact of Nitrogen Levels on Associated Weeds, Fodder Ability and Grain Protein Content of Dual-Purpose Wheat

Impacto dos Níveis de Nitrogênio em Plantas Daninhas Associadas, Capacidade de Forragem e Teor Proteico de Grãos de Trigo de Duplo Propósito

NAVEED, K.[1]
BALOCH, M.S.[2]
QAYYUM, A.[1]
MEHMOOD, A.[1]*
HUSSAIN, I.[1]
ALI, N.[1]

ABSTRACT - Studies were carried out to see the response of dual-purpose wheat to different nitrogen levels i.e. 0, 50, 100, 150 and 200 kg N ha^{-1} in cut (for forage and grain purpose) vs. uncut (for grain only) treatments at the Agriculture Research Institute, Dera Ismail Khan, Pakistan during the years 2009-10 and 2010-11. The results revealed that maximum number of days to heading (123.5 and 124.5), plant height (117.7 and 116.6 cm), grain protein content (11.59 and 12.47%), fresh forage yield (2,646 and 2,956 kg ha^{-1}) and grain yield (4,631 and 4,489 kg ha^{-1}) were recorded in plots that received either 150 or 200 kg ha^{-1} nitrogen respectively and vice-versa. The data indicated higher values for number of days to heading in cut (124.9) as compared to uncut plots (118.9). Uncut plots attained maximum plant height (112.4 cm), leaf area index and duration at 112 DAS (2.82 and 45.2 respectively) and crop growth rate (15.44 g m^{-2} day^{-1}). Significantly lower fresh and dry weed weights were recorded in cut plots as compared to uncut plots while different nitrogen levels did not affect them significantly. Grain protein content was slightly lower in cut plots (11.11%) under different levels of nitrogen as compared to uncut plots (11.24). Dual-purpose wheat resulted in a higher benefit cost ratio as compared to grain-only wheat using higher nitrogen levels. It was concluded from the studies that either 150 or 200 kg ha^{-1} nitrogen can be profitably used for enhancing dual-purpose wheat productivity.

Keywords: crop growth rate, leaf area index, nitrogen levels, crop production.

RESUMO - Foram realizados estudos para verificar a resposta do trigo de duplo propósito a diferentes níveis de nitrogênio (0, 50, 100, 150 e 200 kg N ha^{-1}) em tratamentos com corte (para fins de forragem e produção de grãos) e sem corte (somente para produção de grãos) no Instituto de Pesquisa Agrícola Dera Ismail Khan, Paquistão, durante os anos de 2009-10 e 2010-11. Os resultados revelaram que o número máximo de dias até o espigamento (123,5 e 124,5), a altura de plantas (117,7 e 116,6 cm), o teor proteico de grãos (11,59% e 12,47%), o rendimento de forragem fresca (2.646 e 2.956 kg ha^{-1}) e o rendimento de grãos (4.631 e 4.489 kg ha^{-1}) foram registrados em parcelas que receberam 150 ou 200 kg ha^{-1} de nitrogênio, respectivamente, e vice-versa. Os dados indicaram valores mais altos para o número de dias até o espigamento (124,9), em comparação com as parcelas sem corte (118,9). As parcelas sem corte atingiram maiores altura da planta (112,4 cm), índice e duração da área foliar aos 112 DAS (2,82 e 45,2, respectivamente) e taxa de crescimento da cultura (15,44 gm^{-2} dia^{-1}). Foram registrados pesos fresco e seco de plantas daninhas significativamente menores

*** Corresponding author:**
<ayaz.gill@uoh.edu.pk>

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[1] University of Haripur, Pakistan; [2] Gomal University, Dera Ismail Khan, Pakistan.

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nas parcelas com corte, em comparação com parcelas sem corte, mas não houve influência significativa dos diferentes níveis de nitrogênio. O teor proteico dos grãos foi ligeiramente menor nas parcelas com corte (11,11%) sob diferentes níveis de nitrogênio, em comparação com as parcelas sem corte (11,24). O trigo de duplo propósito resultou em maior custo-benefício em comparação com o trigo somente para grãos, utilizando níveis mais altos de nitrogênio. Concluiu-se, a partir dos estudos, que o nitrogênio a 150 ou 200 kg ha^{-1} pode ser utilizado de forma lucrativa para melhorar a produtividade do trigo de duplo propósito.

Palavras-chave: taxa de crescimento de culturas, índice de área foliar, níveis de nitrogênio, produtividade de culturas.

INTRODUCTION

The aim of any crop production system is to provide inputs to a level where the output pays more than the input, or to apply the economic optimum. Cereal crops are used throughout the world for livestock feed. Growing wheat as a dual-purpose crop (forage + grain) has been reported as a practice in different countries in the world including USA, Argentina, Morocco, Pakistan. Moreover, it is a way for growers to increase their income from their wheat operation. The rate of regrowth following clipping or grazing is crucial for the productivity of the grazing component of a dual-purpose system. “Regrowth” highly depends on the amount and timing of rainfall, growing degree days, radiation and availability of nutrients in the soil profile for plants to uptake. Naveed et al. (2014) reported that different seeding rates had a non-significant effect on plant height and grain yield of wheat. Khaliq et al. (2008) found that awn detachment exhibited less effect on yield and yield related characters as compared to flag leaf detachment, while detachment of both of them had more significant effects than individual treatment.

Nitrogen plays an important role in supporting grain yield and grain protein content of wheat (Ehdaie and Waines, 2001). Nitrogen is deficient in Pakistani soils as a result of their calcareous nature with pH ranging from 8-9 (Bhatti et al., 1993). In addition, nitrogen is also found in chlorophyll, the green pigment of leaves. Therefore, nitrogen supplies to plants influence cell size and leaf area, photosynthetic activity and finally forage and grain yield. Naveed et al. (2015) found that the two important yield-contributing parameters i.e., number of productive tillers and grain spike^{-1} were significantly higher in early sown wheat than late sown wheat.

Abril et al. (2007) showed that the highest fertilization rate resulted in a negative nitrogen balance, highest nitrogen losses with no significant increase in yield. A higher dose of nitrogen often results in increased leaf are index but the greatest difference during maturation is the ability to maintain a larger number of green leaves late in the season compared with low nitrogen fertility levels. The use of nitrogen poses a potential threat to biodiversity as a result of leaching when over applied to fields (Tilman, 1999). Therefore, the challenge for the next decades will be to accommodate the needs of the expanding world population by developing highly productive agriculture, whilst at the same time preserving the quality of the environment (Dyson, 1999).

Weeds deplete the soil from nutrients and compete with crops for resources. Wheat crop is plagued by different kinds of narrow and broadleaf weeds which negatively affect growth and yield. The most common approach for weed control nowadays is the use of herbicides; although it is an effective and quick method of weed control, it is not environmentally suitable. It is the right time to devise strategies that could lead to weed control and which are environment friendly and cost effective. Although weeds cannot be eliminated altogether, competition against weeds can be managed in favor of crops. Such a strategy could best be achieved in the shape of dual purpose wheat cultivation. Tariq et al. (2013) also reported the decline in weed fresh and dry weight as a result of cutting in brassica crops.

Protein is considered as the most important nutrient for humans and animals and is found in wheat forage and grains as well. Khalil et al. (2002) found that under proper management, grain produced in dual-purpose wheat is similar in quality with that of grain-only wheat. The effect of forage removal on grain yield in grain crops is a complex process which depends on environmental conditions, stocking pressure, management practices, fertility status, variety in use and stage of cutting. Unfortunately, there is little or no information available on production practices, including fertility programs, in dual use wheat/stocker systems. The determination of optimum amount of nitrogen for successful raising of dual-purpose wheat (grain only and fodder + grain) was therefore imperative and so was its interactive effects on weed population and protein content of wheat grains under the cropping system of Dera Ismail Khan, Pakistan.

MATERIALS AND METHODS

Five nitrogen levels viz. 0, 50, 100, 150 and 200 kg N ha^{-1} as Factor A and cutting (cut vs uncut) as Factor B were tested at the Agriculture Research Institute, Dera Ismail Khan (31° 49 N and 70° 55 E), Khyber Pakhtunkhwa (KP), Pakistan during the years 2009-10 and 2010-11. The experiment was laid out in a randomized complete block design (factorial) with four replicates. Recommended doses of phosphorous and potassium fertilizers were applied to all treatments at 120-90 kg ha^{-1} in the form of Triple Super Phosphate and Sulphate of Potash, respectively, while urea as a source of nitrogen fertilizer was applied in split form i.e., half amount of nitrogen was applied at the time of sowing while the remaining half amount of nitrogen was applied with the first irrigation. All the phosphorous and potash were applied at the time of sowing. Wheat variety Zam-04 was sown in a plot size of 5 m x 1.8 m with 6 rows of 5 m in length. All agronomic and cultural operations were followed as suggested by Shah (1994). Half of the plots (treatments) were cut at 60 days after wheat sowing to obtain fresh forage and compare these with those half left uncut treatments for other attributes. The experimental site had a mild winter as revealed by the metrological data of the test site i.e., minimum temperature of 4 °C in December and January and maximum temperature of 35.5 °C in April in both years with organic matter ranging between 0.60-0.87%, potassium (270-85 ppm), nitrogen (0.033-0.032%) and phosphorous (6.0-7.0 ppm). The mean annual precipitation ranges from 15-25 cm and relative humidity varies from 51% in June to 78% in October. The field was prepared by one deep ploughing and then with a cultivator followed by a rotavator and planking to ensure a firm seedbed. The field was prepared in such a way as to destroy weeds, etc. The crop was sown with a man-driven hand drill. The stubbles of previous crop were incorporated into the soil to add organic matter. Irrigation was applied through flooding at crown root initiation, tillering, jointing, booting, flowering and grain development stages. The data on leaf area index (LAI), leaf area duration (LAD) at 112 days after sowing (DAS), crop growth rate (CGR), weeds fresh and dry weight, plant height, days to heading, grain and fresh forage yield (kg ha^{-1}), benefit cost ratio (BCR) and grain protein content (%) were recorded and analyzed statistically using the analysis of variance technique (Steel et al., 1997) and subsequently the least significance difference (LSD) test was applied for comparing the treatment means by the computer software MSTATC (MSTATC, 1991).

RESULTS AND DISCUSSION

Leaf area index at 112 days after sowing: Leaf area is usually influenced by genotype, plant population climate and soil fertility condition (Murphy et al., 1996). Cutting vs non-cutting treatments had a significant ($p<0.05$) effect on LAI at 112 DAS in both years (Table 1). In the year 2009-10, higher LAI (2.82) was recorded in the uncut treatment which was significantly different from LAI of 2.16 obtained in cut plots. The trend of producing LAI was the same during the second year of study. The reason for producing higher LAI in the uncut treatment was possibly due to non-cutting of wheat, which resulted in uninterrupted growth of wheat and vice-versa. The effect of nitrogen levels showed significant ($p<0.05$) variations in LAI during both years of experimentation. Maximum LAI (4.0) was noted in plots fertilized at 200 kg N ha^{-1}, followed by 150 kg ha^{-1} while the lowest LAI (1.23) was recorded in control plots during the first year of study. The second-year results showed a similar trend of increasing LAI with higher nitrogen levels. The higher nitrogen fertilization might have increased the number of leaves and their expansion and, hence, leaf area index in wheat. The increase in leaf area index with increase in N application might be the effect of increased rate of leaf expansion and increased leaf number. The significant increase in leaf area was recorded which was found to be more responsive with the increase in the level of nitrogen (Guru et al., 1999). Jamaati-e-Somarin et al. (2009) also showed that with increasing nitrogen application, number of leaves and tillers and leaf chlorophyll content were increased. There was a significant ($p<0.05$) interaction among nitrogen levels and

Table 1 - Leaf area index, leaf area duration and crop growth rate (g m^{-2} day^{-1}) as affected by nitrogen levels and cutting vs non-cutting treatments in dual-purpose wheat during the years 2009-10 and 2010-11

Parameter	Nitrogen level (kg ha^{-1})	2009-10			2010-11		
		Uncut	Cut	Mean	Uncut	Cut	Mean
Leaf area index (112 DAS)	0	1.32 g	1.13 g	1.23 E	1.37 NS	1.13	1.25 E
	50	1.86 f	1.41 g	1.64 D	2.16	1.84	2.00 D
	100	2.62 e	1.99 f	2.30 C	2.76	2.47	2.61 C
	150	3.69 b	2.91 d	3.30 B	4.10	3.74	3.92 B
	200	4.62 a	3.38 c	4.00 A	4.85	4.17	4.51 A
	Mean	2.82 A	2.16 B		3.05 A	2.67 B	
Leaf area duration (112 DAS)	0	21.26 g	18.14 g	19.70 E	21.92 NS	18.13	20.03 E
	50	29.90 f	22.63 g	26.26 D	34.68	29.50	32.09 D
	100	41.97 e	31.84 f	36.90 C	44.15	39.61	41.88 C
	150	59.06 b	46.67 d	52.87 B	65.67	59.83	62.75 B
	200	73.93 a	54.13 c	64.03 A	77.60	66.73	72.17 A
	Mean	45.22 A	34.68 B		48.80 A	42.76 B	
Crop growth rate (g m^{-2} day^{-1})	0	10.01 NS	8.65	9.33 D	7.43 NS	5.30	6.36 C
	50	11.78	10.44	11.11 C	10.04	7.45	8.74 B
	100	13.46	12.55	13.01 B	9.77	8.45	9.11 B
	150	19.84	18.10	18.97 A	12.68	10.71	11.70 A
	200	22.10	17.69	19.90 A	13.93	11.18	12.56 A
	Mean	15.44 A	13.48 B		10.77 A	8.62 B	

Means followed by different letters in a column are different at 5% level of probability.

cutting vs. non-cutting treatments but the interaction remained non-significant ($p>0.05$) during the second year of research. The uncut treatment receiving 200 kg N ha^{-1} had higher LAI (4.62). The minimum and statistically at par LAI (1.13, 1.32 and 1.41) was obtained in the cut and uncut plots of control and cut plots of 50 kg N ha^{-1} treatments, respectively. The highest LAI value found in the plots with the highest nitrogen fertilization rate was possibly due to the net effect of nitrogen while the lower LAI value obtained in cut treatment of control plots might be the result of double stress of cutting and no nitrogen application at all.

Leaf area duration (112 DAS): The data showed significant ($p<0.05$) differences among cutting vs. non-cutting treatments at 112 DAS in both years (Table 1). During the year 2009-10, maximum LAD (45.22) was recorded in the uncut treatment as compared to LAD (34.68) recorded in the cut treatment. A similar trend was found during the year 2010-11. Different nitrogen levels showed a significant ($p<0.05$) effect on LAD in both years of research. During the first year, maximum LAD (64.03) was recorded with the use of 200 kg ha^{-1} followed by 150 kg N ha^{-1} (52.87) while minimum LAD (19.70) was recorded in the control plots. The data recorded during the second year showed a similar trend. The reason why higher LAD was found in the plots receiving maximum nitrogen was probably due to maximum photosynthetic activity that had resulted in increased leaf area. Ali et al. (2010) also found that leaf area index and leaf area duration increased with increased level of nitrogen application. The interaction among nitrogen levels and cutting vs. non-cutting treatments showed significant ($p<0.05$) variations in the first year and non-significant ($p>0.05$) in the second year of the study. Uncut plots fertilized with 200 kg ha^{-1} nitrogen recorded the highest LAD (73.93). The minimum and statistically at par LAD (18.14 and 21.26) was noted in cut and uncut treatments of the control plots, respectively. Cut plots with 50 kg N ha^{-1} also had minimum and statistically at par LAD (22.63). The reason of maximum leaf area duration might be the absence of cutting stress and availability of maximum amount of nitrogen.

Crop growth rate (g m^{-2} day^{-1}): Crop growth rate (CGR) was significantly ($p<0.05$) affected by cutting vs. non-cutting treatments and nitrogen levels in both years (Table 1). During the year 2009-10, maximum CGR (15.44) was obtained in the uncut as compared to the cut treatment (13.48). The year 2010-11 also showed a similar response of increased CGR in the uncut treatment followed by the cut treatment. The decapitation effect might be responsible for lower plant weight obtained in cut plots. During the first year of research, maximum and statistically at par CGR (19.90 and 18.97) was recorded with 200 and 150 kg N ha^{-1}, followed by 100 kg N ha^{-1} (13.01) while minimum CGR (9.33) was noted in the control plots. The trend of CGR in the second year of study was the same: it increased with increasing nitrogen levels. The reason of higher CGR might be the availability of nitrogen, which is the main constituent of chlorophyll and resulted in higher photosynthetic activity and higher CGR. Sarkar and Saha (2005) also concluded that application of nitrogen improved physiological parameters such as biomass production and crop growth rate. According to Fluegel and Johnson (2001), higher nitrogen had a positive effect on growth and dry matter production. Ali et al. (2010) also found increased crop growth rate with increasing level of nitrogen.

Fresh and dry weeds weight (g m^{-2}): The data indicated that fresh and dry weight of weeds was significantly ($p<0.05$) affected by cutting vs. non-cutting treatments while the effect of nitrogen levels was non-significant in both years of study (Table 2). In the experiment, the effect of nitrogen was the least observable while cutting had a significant effect on weed weight. During the first year, maximum weed fresh and dry weights were recorded in the uncut plots whereas cut plots recorded the lowest fresh and dry weed weights. In the second year of study, there was a similar trend. The possible reason for lower fresh and dry weed weight in the uncut treatment might be due to cutting shock, which would have resulted in weed suppression and vice-versa. Similar findings were reported by Tariq et al. (2013), who stated a decline in weed fresh and dry weight as a result of cutting in brassica crops. There was a significant interaction between cutting and nitrogen levels for weed fresh and dry weights in both years of experimentation. During the year 2009-10, maximum and statistically at par fresh and dry weed weights were recorded in the uncut plots with all the levels of nitrogen including control (0 kg ha^{-1}) while minimum and statistically similar fresh and dry weed weights were recorded in cut treatments with all the levels of nitrogen including control (0 kg ha^{-1}). There was an almost similar trend was in the second year of research. Cutting of wheat for fodder might have resulted in cutting of weeds along with it thereby reducing fresh weed weight and, ultimately, dry weed weight.

Table 2 - Weed fresh and dry weight (g m^{-2}) as affected by nitrogen levels and cutting vs non-cutting treatments in dual-purpose wheat during the years 2009-10 and 2010-11

Parameter	Nitrogen level (kg ha^{-1})	2009-10			2010-11		
		Uncut	Cut	Mean	Uncut	Cut	Mean
Weeds fresh weight (g m^{-2})	0	418.5 a-c	296.5 d	357.5 NS	460.5 a-c	304.7 d	382.6 NS
	50	464.0 ab	299.7 d	381.9	477.5 a-c	349.5 b-d	413.5
	100	504.0 a	332.0 cd	418.0	494.5 ab	389.7 a-d	442.1
	150	483.5 a	358.7 b-d	421.1	503.50 a	342.5 cd	423.0
	200	504.5 a	327.7 cd	416.1	499.0 ab	362.5 a-d	430.8
	Mean	474.9 A	322.9 B		487.0 A	349.8 B	
Weeds dry weight (g m^{-2})	0	49.00 a-d	34.50 d	41.75 NS	54.5 abc	33.8 d	88.3 NS
	50	53.75 a-c	31.25 d	42.50	56.5 ab	35.0 cd	91.5
	100	62.75 a	40.50 b-d	51.62	57.3 a	44.8 a-d	102.1
	150	59.50 ab	44.00 a-d	51.75	62.0 a	43.5 a-d	105.5
	200	58.75 ab	37.25 cd	48.00	58.0 a	36.5 bcd	94.5
	Mean	56.75 A	37.50 B		288.3 A	198.1 B	

Means followed by different letters in a column are different at 5% level of probability.

Plant height at maturity (cm): The data indicated that plant height was significantly ($p<0.05$) affected by cutting vs. non-cutting treatments and nitrogen levels in both years of study (Table 3). During the first year, taller plants of 112.4 cm were recorded in uncut treatment whereas cut plots produced short-statured plants of 103.9 cm. In the second year of study, the trend of plant height was the same. The possible reason of taller plants in the uncut treatment might be the absence of cutting shock with no interruption in plant growth and vice-versa. Noy-Meir and Briske (2002) also found that, in the case of uncut plots, there was no interruption in plant growth and thus, those plants were the tallest. Khalil et al. (2011) stated that no cutting produced the tallest wheat plants. During the year 2009-10, the tallest (117.7 cm) plants were found in plots receiving 150 kg N ha^{-1}. It was however, statistically at par (116.6 and 113.8 cm) with treatments receiving 200 and 100 kg N ha^{-1}, respectively. Short statured-plants of 83.9 cm were produced in the control. There was an almost similar trend of plant height in the second year of research. The role of nitrogen in increasing vegetative growth might be the cause of taller plants produced in the treatments with higher levels of nitrogen. Fluegel and Johnson (2001)

Table 3 - Plant height (cm), days to heading and grain yield (kg ha^{-1}) as affected by nitrogen levels and cutting vs non-cutting treatments in dual-purpose wheat during the years 2009-10 and 2010-11

Parameter	Nitrogen level (kg ha^{-1})	2009-10			2010-11		
		Uncut	Cut	Mean	Uncut	Cut	Mean
Plant height (cm)	0	90.7 ^{NS}	77.1	83.9 C	90.7 f	77.53 g	84.1 D
	50	112.8	104.7	108.8 B	111.9 cd	105.1 e	108.5 C
	100	118.3	109.2	113.8 A	114.9 bc	110.2 d	112.6 B
	150	121.2	114.1	117.7 A	120.1 a	116.0 b	118.0 A
	200	118.9	114.3	116.6 A	120.0 a	117.3 ab	118.7 A
	Mean	112.4 A	103.9 B		111.5 A	105.2 B	
Days to heading	0	116.2 ^{NS}	122.5	119.4 E	115.0 ^{NS}	121.2	118.1 E
	50	117.2	123.7	120.5 D	117.2	123.0	120.1 D
	100	119.0	124.7	121.9 C	119.5	125.0	122.3 C
	150	120.5	126.5	123.5 B	120.7	126.5	123.6 B
	200	121.7	127.2	124.5 A	122.0	127.7	124.9 A
	Mean	118.9 B	124.9 A		118.9 B	124.7 A	
Grain yield (kg ha^{-1})	0	1164 ^{NS}	1046.7	1105 D	1131 ^{NS}	1094.7	1113 D
	50	2902.0	2506.2	2704 C	3067.5	2998.7	3033 C
	100	3962.7	3821.0	3892 B	3916.2	3773.7	3845 B
	150	4733.2	4528.0	4631 A	4798.5	4639.0	4719 A
	200	4344.2	4633.2	4489 A	4599.2	4695.2	4647 A
	Mean	3421 ^{NS}	3307.0		3502 ^{NS}	3440.3	

Means followed by different letters in a column are different at 5% level of probability.

also reported that higher nitrogen levels had a positive effect on plant height. The interaction among nitrogen levels and cutting vs. non-cutting treatments showed non-significant variations during the year 2009-10 while there was a significant ($p<0.05$) interaction in 2010-11. The data revealed that significantly ($p<0.05$) taller plants (120.1 cm) were produced in uncut plots receiving 150 kg N ha^{-1}. It was however, statistically at par (120.0 and 117.3 cm) with uncut and cut plots with the highest nitrogen rate of 200 kg ha^{-1}, respectively. Minimum plant height (77.5 cm) was recorded in cut plots without N fertilization. The reason for taller plants might be availability of optimum amount of nitrogen fertilizer and absence of decapitation stress. Bilal et al. (2000) also elucidated that plant height increased significantly in mott grass (*Pennisetum purpureum*) with nitrogen application over control at all growth stages in all cuttings.

Days to heading: Cutting vs. non-cutting treatments showed a statistically significant ($p<0.05$) effect on number of days to heading in both years (Table 3). A greater number of days (124.9) to heading was recorded in cut plots as compared to the uncut treatment (118.9) in the first year. The second-year results also showed a similar trend a maximum of 124.7 days to heading in cut plots and a minimum of 118.9 days to heading in uncut plots. The reason of delay in heading in cut plots might be the fact that wheat is cut for use as forage, which extended the vegetative growth period. Khalil et al. (2011) also found a delay in days to heading in wheat after cutting. The effect of nitrogen levels was also significant ($p<0.05$) for number of days to heading in both years of experimentation. The first-year data showed a higher number of days to heading (124.5) in the plot that received 200 kg N ha^{-1} while minimum days to heading (119.4) were taken by the crop without application. There was the same trend in the second year of research. The reason for maximum days to heading might be the use of the maximum amount of nitrogen, which resulted in prolonged vegetative growth duration and vice versa. The results are in line with those of Khalil et al. (2011), who found that plots with the highest nitrogen level took more days (126.8) to heading.

Grain yield (kg ha^{-1}): The data in Table 3 show that cutting vs. non-cutting treatments had a non-significant effect on grain yield in both the years of research. Under optimal soil fertility and moisture conditions and timely termination of grazing, grain yield in winter wheat is the least affected by grazing (Redmon et al., 1995). Cutting of green fodder resulted in a non- significant difference in yield (Bisht et al., 2008). Lyon et al. (2001) also found insignificant losses in grain yield after forage removal. Zhu et al. (2004) concluded that defoliation of early sown wheat, at the middle to late tillering stage, did not result in yield reduction. McCormick et al. (2009) also found that there was no difference in final grain yield between grazed and ungrazed plots. Naveed et al. (2015) found non-significant effects of cutting on number of spikes and grain yield in dual-purpose wheat. The same author in another trial (Naveed et al., 2014) further validated these results and explored that different seeding densities had a non-significant effect on grain yield of dual-purpose wheat. Experimentation on winter wheat has depicted that grazing termination before first hollow stem development did not have an effect on grain yield and vice versa (Fieser et al., 2004). The effect of different nitrogen levels on grain yield showed significant differences in both years of experimentation. During the year 2009-10, maximum grain yield (4,631 kg ha^{-1}) was recorded in plots receiving 150 kg N ha^{-1}. Plots with 200 kg N ha^{-1}, however, recorded statistically at par with grain yield (4,489 kg ha^{-1}). There was minimum grain yield (1,105 kg ha^{-1}) in the control plots. There was no change in the trend of the data during the year 2010-11 wherein grain yield had a progressive increase with increased nitrogen level. The reason for maximum grain yield achieved in rich N fertilized plots might be optimum availability of nitrogen, the deficiency of which affects various plant growth processes. Deficiency of nitrogen results in reduced cell division and elongation while excess of nitrogen prolongs the growth period with consequent delay in crop maturity (Tisdale and Nelson, 1966). Nitrogen, as a result of its highly mobile nature, is one of the most essential crop nutrients for optimizing grain yield (Koch et al., 2004). Wheat yield and yield components increased with nitrogen application up to 150 kg N ha^{-1}, compared with the control (Waraich et al., 2007; Ahmad et al., 2007). Subedi et al. (2007) demonstrated that grain yields were increased with nitrogen application. Waraich et al. (2002) also found increased grain yield with an increase in nitrogen levels. Singh et al. (1993) and Behera (1995) reported that application of 100% of the recommended fertilizer recorded higher grain yield than the 50% of the recommended fertilizer and the control. The interaction among different nitrogen levels and cutting vs. non-cutting treatments showed non-significant ($p>0.05$) variations in both years of study.

Grain protein content (%): Although grain protein content in wheat depends upon genetic make-up yet it is also influenced by environmental variables such as nitrogen application, water availability and temperature during growth, especially in the grain filling period (Daniel and Triboi et al., 2000; Luo et al., 2000; Ottman et al., 2000; Rharrabti et al., 2001; Altenbach et al., 2002; Dupont and Altenbach, 2003; Tea et al., 2004). The data on grain protein content percentage (Table 4) showed that it was slightly lower in cut plots (11.11%) as compared to uncut plots (11.24%) during the first year of research. The second-year results also showed a similar trend. The possible reason for lower % GPC in cut plots might be removal of photosynthetic plant parts for forage production and lighter grains as compared to uncut plots. Application of different nitrogen levels had a direct effect on % GPC and increased linearly with an increase in the level of nitrogen applied in both years of experimentation. During the first year, maximum % GPC (12.47) was found in plots that received 200 kg N ha^{-1} while minimum % GPC (9.52) was found in the control. The second-year results showed a similar trend. The reason for higher % GPC might be attributed to application of higher levels of nitrogen fertilizer, which encouraged the absorption

Table 4 - Grain protein content (%) and fresh forage yield (kg ha^{-1}) as affected by nitrogen levels in dual-purpose wheat during the years 2009-10 and 2010-11

Parameter	Nitrogen level (kg ha^{-1})	2009-10			2010-11		
		Uncut	Cut	Mean	Uncut	Cut	Mean
Grain protein content (%)	0	9.41	9.63	9.52	10.06	9.41	9.73
	50	11.16	11.38	11.27	10.94	11.16	11.05
	100	11.16	10.94	11.05	10.94	10.94	10.94
	150	11.81	11.38	11.59	11.59	12.03	11.81
	200	12.69	12.25	12.47	12.03	11.59	11.81
	Mean	11.24	11.11		11.11	11.03	
Fresh forage yield (kg ha^{-1})	0	-	-	1114 C	-	-	744.2 E
	50	-	-	1398 C	-	-	1382 D
	100	-	-	2007 B	-	-	2090 C
	150	-	-	2646 A	-	-	2833 B
	200	-	-	2956 A	-	-	3087 A

Means followed by different letters in a column are different at 5% level of probability.

of nitrogen in the plant. Other researchers also reported increased grain N as applied N increased (Kelley, 1995; Woodard and Bly, 1998). Bakht et al. (2009) also reported that grain N content increased as applied N increased. Staggenborg et al. (2003) found an increase in nitrogen content of grains with increased nitrogen application.

Fresh forage yield (kg ha^{-1}): Different nitrogen levels significantly affected fresh forage yield of wheat and it showed an almost similar trend of producing more forage with increased level of nitrogen applied in both years of study (Table 4). Maximum and statistically at par fresh forage yield of 2956 was recorded with nitrogen levels of 200 and 150 kg ha^{-1} during the year 2009-10, respectively and statistically at par with fresh forage yield (1,114 and 1,398 kg ha^{-1}) which was, however, obtained in check and 50 kg N ha^{-1} applied plots, respectively. During the year 2010-11, maximum fresh forage yield (3,087 kg ha^{-1}) was recorded in plots receiving 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (2,833 kg ha^{-1}) while the control treatment produced lower fresh forage yield of 744 kg ha^{-1}. The reason for higher fresh forage yield obtained with the higher nitrogen levels might be enhanced photosynthetic activity that resulted in higher LAI, plant height and CGR while the reverse was true for either no nitrogen at all or plots receiving minimum nitrogen. These results are supported by Kanampiu et al. (1995) who concluded that forage and grain yield increased with increasing nitrogen levels.

Benefit cost ratio (BCR): The data on benefit cost ratio (Tables 5 and 6) showed that dual-purpose (forage + grain) wheat had higher net income and BCR as compared to grain-only wheat using different nitrogen levels in both years of research. During the first year, maximum net

Table 5 - Benefit cost ratio (BCR) as affected by different nitrogen levels and cutting vs non-cutting treatments in dual-purpose wheat during the year 2009-10

Nitrogen level (kg ha^{-1})	Cost			Income				Net Income US $	BCR
	Fixed	Variable	Total	Grains	Fodder	Straw	Total		
0 x uncut	412.6	0.0	412.6	250.5	0.0	33.3	283.8	-128.8	0.69
0 x cut	412.6	17.1	429.8	225.4	53.0	29.9	308.3	-121.4	0.72
50 x uncut	412.6	17.6	430.2	624.6	0.0	82.9	707.5	277.3	1.64
50 x cut	412.6	34.7	447.4	539.4	66.6	71.6	677.6	230.2	1.51
100 x uncut	412.6	35.2	447.8	853.0	0.0	113.2	966.2	518.4	2.16
100 x cut	412.6	52.3	465.0	822.4	95.6	109.2	1027.2	562.2	2.21
150 x uncut	412.6	52.8	465.4	1018.7	0.0	135.2	1153.9	688.6	2.48
150 x cut	412.6	69.9	482.5	974.6	126.0	129.4	1230.0	747.4	2.55
200 x uncut	412.6	70.4	483.0	935.0	0.0	124.1	1059.1	576.1	2.19
200 x cut	412.6	87.5	500.1	997.2	140.8	132.4	1270.3	770.2	2.54

Rate of wheat seed = 0.22 US $ kg^{-1}; Rate of wheat fodder = 0.048 US $ kg^{-1}; Cutting of wheat fodder = 17.14 US $ ha^{-1}; Rate of urea = 8.10 US $ per bag; Rate of wheat straw = 2.86 US $ per 100 kg grains.

Table 6 - Benefit cost ratio (BCR) as affected by different nitrogen levels and cutting vs non-cutting treatments in dual-purpose wheat during the year 2010-11

Nitrogen level (kg ha^{-1})	Cost			Income				Net Income US $	BCR
	Fixed	Variable	Total	Grains	Fodder	Straw	Total		
0 x uncut	470.5	0.0	470.5	237.0	0.0	37.7	274.7	-195.8	0.58
0 x cut	470.5	17.1	487.6	229.4	35.4	36.5	301.3	-186.3	0.62
50 x uncut	470.5	21.7	492.2	642.7	0.0	102.2	745.0	252.7	1.51
50 x cut	470.5	38.9	509.4	628.3	65.8	100.0	794.1	284.7	1.56
100 x uncut	470.5	43.5	514.0	820.5	0.0	130.5	951.1	437.1	1.85
100 x cut	470.5	60.6	531.1	790.7	99.5	125.8	1016.0	484.9	1.91
150 x uncut	470.5	65.2	535.7	1005.4	0.0	159.9	1165.3	629.6	2.18
150 x cut	470.5	82.4	552.8	972.0	134.9	154.6	1261.5	708.7	2.28
200 x uncut	470.5	87.0	557.4	963.6	0.0	153.3	1116.9	559.5	2.00
200 x cut	470.5	104.1	574.6	983.8	147.0	156.5	1287.3	712.7	2.24

Rate of wheat seed = 0.21 US $ kg^{-1}; Rate of wheat fodder = 0.048 US $ kg^{-1}; Cutting of wheat fodder = 17.14 US $ ha^{-1}; Rate of urea = 10.0 US $ per bag; Rate of wheat straw = 3.33 US $ per 100 kg grains.

income (US $ 770.2) was found in cut plots using the highest nitrogen level of 200 kg ha^{-1} while uncut plots in control negatively affected net income (US $ -128.8). Maximum BCR (2.55) was obtained in cut plots receiving 150 kg N ha^{-1} while it was minimum (0.69) in uncut plots of the control treatment. The second-year results also showed a similar trend. The possible reason of higher net income and BCR might be due to the income generated by forage and grain yield as compared to other plots. These findings are in line with those of Sij et al. (2007), who found that the graze-plus-grain system was clearly better than the graze-out system at generating higher net returns.

Based on the results, it was found that higher fresh forage and grain yield were achieved with the use of higher nitrogen levels. Grain protein content was slightly lower in cut plots but it increased with higher levels of nitrogen. Cutting wheat for fodder significantly reduced weed weight while the uncut treatment recorded higher weed weight, showing less control than the cut treatment. Therefore, it is recommended that either 150 or 200 kg nitrogen ha^{-1} should be used for successful raising of both grain-only and fodder plus grain wheat with subsequent control of weed populations without compromising grain quality.

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