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EFFECT OF TIME OF NITROGEN APPLICATION ON MORPHOLOGICAL AND PHYSIOLOGICAL ATTRIBUTES OF DUAL-PURPOSE WHEAT

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Abstract

Wheat can be used as dual-purpose (forage and grain) crop, however, to avoid loss in grain yield, it requires proper fertilizer and crop management practices. In order to assess the effects of nitrogen time of application on growth and yield components of dual-purpose wheat, an experiment was conducted at the Agricultural Research Institute, Dera Ismail Khan, during the years 2009-10 and 2010-11. The results revealed that maximum number of productive tillers (m^{-2}), number of grains spike^{-1}, leaf area index and duration (112 days after sowing), crop growth rate and grain yield was obtained in plots that received 75% recommended dose of nitrogen after cut. Fresh and dry forage yield were maximum either when full dose or 75% of recommended nitrogen was applied at sowing. Leaf area index and duration (56 days after sowing) was maximum when full dose of recommended nitrogen was applied at sowing. Minimum plant height was recorded in control plots. Split application of nitrogen increased grain protein content over sole or no application of nitrogen in dual-purpose wheat. The application of nitrogen either in two equal splits or 25% applied at sowing and 75% after cut resulted in increased benefit cost ratio.

Introduction

Pakistan, being developing country, faces food and energy shortage, so there is a need to use the existing resources efficiently. Commercial fertilizer is one of the energy sources used for maximum wheat production. The available fertilizers, especially N fertilizers, are used lavishly in Pakistan's agriculture, so the effectiveness with which N is used by wheat and other cereals has become increasingly important. N management plays a key role in improving crop yield and quality, environmental safety and economics of crop production (Campbell *et al*., 1995; Maqsood *et al*., 2012). Abedi *et al*., (2011) concluded that not only increasing the N fertilization rate but also N timing had a beneficial effect on grain yield and its quality.

Grain protein levels may increase with late-season N applications. Woolfolk *et al*., (2002) found that late-season foliar N applications before or immediately following flowering significantly enhanced grain N content and thus percent protein in winter wheat. The pre-plant applications may lead to losses or immobilization before plant uptake, thus greatly affecting N use efficiency (NUE). To avoid nitrogen losses as a result of leaching and volatilization, split application is needed. Pre-plant applied N is subject to leaching and prone to de-nitrification or immobilization before plant uptake, thus affecting N use efficiency (Subedi *et al*., 2007).

Wheat is one of the most versatile small grains for a farming operation. Wheat serves three very important purposes. First, it is a cool-season forage crop for grazing livestock. Second, it is used as a grain crop. Third, it is used for both forage and grain production. Livestock graze forage during fall and winter and grain is produced during spring after livestock are removed. Wheat can be used for these three purposes because it is adapted to a wide range of climates and soil types. Optimizing fertilizer N use, achieving acceptable forage and grain yield and maintaining adequate grain protein requires knowledge of expected N uptake efficiency and utilization within the plant in relation to the rate and timing of N applied. Bisht *et al*., (2008) had the view that cutting of green fodder scheduled at 70 and 85 days resulted in non-significant difference in yield.

In winter wheat, N applications are performed in a split way (Kichey *et al.,* 2007). Traditional uniform N applications, in most cases, result in over and under application of N in various parts of the field due to in-field spatial variability (Frasier *et al*., 1999; Khosla *et al*., 1999). The ability to variably apply optimum levels of N fertilizer corresponding to site-specific field conditions has been shown to increase N use efficiency, grain yields, crop quality, and net dollar returns while decreasing nutrient overload (Prato & Kang, 1998). Design of fertilizer application regimes should combine rate, timing, splitting, and source of application, with a view to optimizing wheat yield and its quality (Borghi, 2000; Grant *et al*., 2001; Blankenau *et al*., 2002). Abedi *et al*., (2011) concluded that high wheat grain yield beside a suitable bakery quality and without environmental impact of N over application were possible with sufficient N application during vegetative growth for yield and late season N application for protein quality.

To maintain crop yields and reduce losses of N and increase the profit of our farmers it is important to utilize N applied to crops as efficiently as possible. The best agricultural technique to reduce losses of N is through split application.. Therefore, the study in hand was carried out to ascertain the time and amount of nitrogen application on wheat grown for forage and grain purpose.

Materials and Methods

The experiment was laid out in a randomized complete block design using five timing of nitrogen application viz., 0% of recommended nitrogen dose before sowing + 0% of recommended nitrogen dose after cut, 100% of recommended nitrogen dose before sowing + 0% of recommended nitrogen dose after cut, 75 % of recommended nitrogen dose before sowing + 25% of recommended nitrogen dose after cut, 50 % of recommended nitrogen dose before sowing + 50% of recommended nitrogen dose after cut and 25% of recommended nitrogen dose before sowing + 75% of recommended nitrogen dose after cut at Agricultural Research Institute, Dera Ismail Khan during the wheat growing seasons of 2009-10 and 2010-11. The net plot size was 1.8x5m^2 having 6 rows, 5m long and 30 cm apart. The seed rate used was 100 kg ha^{-1}. Fertilizer was applied @150- 120-90 NPK kg ha^{-1} in the form of Urea, Triple Super Phosphate and Sulphate of Potash, respectively. All the phosphorous and potash were applied at the time of sowing while nitrogen was applied as per treatment requirement. All agronomic and cultural operations were followed according to Shah (1994). A cut was given to all the treatments after 60 days after sowing (DAS) just before the appearance of first hollow stem. Weedicide Buctril Super and Puma Super were applied @ 750 ml ha^{-1} for the control of broad and narrow leaved weeds. The soil of the experimental site was silty clay having pH 8.82 and < 1% organic matter (Table 1). The metrological data of the test site revealed maximum temperature in April (37^{o}C) and minimum of 3^{o}C in December and January (Table 2). The data on leaf area indices and duration (56 and 112 days after sowing), crop growth rate, plant height (cm) at maturity, number of productive tillers m^{-2}, number of grains spike^{-1}, grain yield (kg ha^{-1}), fresh and dry forage yield (kg ha^{-1}), grain protein content (%) and benefit cost ratio were recorded, compiled and analyzed statistically (Steel & Torrie, 1997) using MSTATC computer software. Least significant difference (LSD) test was used to see the difference among treatment means.

Table 1. Physio-chemical characteristics of soil at Agricultural Research Institute, Dera Ismail Khan.

Symbol	Unit	Values	
		2009	2010
Textural class	-	Silty clay	Silty clay
pH (1:5)	1-14	8.2	8.2
Ex. Na	mmol/100g	0.4	0.38
EC	(1:2.5) dS/m	0.38	0.41
K	ppm	270	285
Organic matter	%	0.60	0.87
N	%	0.033	0.0323
P	ppm	6.0	7.0

Source: Soil Chemistry Laboratory, Agriculture Research Institute, D.I. Khan, Pakistan

Table 2. Average monthly maximum and minimum temperature and rainfall during 2009-2010 and 2010-2011 at ARI, D.I. Khan.

Month	2009-10			2010-11		
	Temp. (^{o}C)		Rainfall (mm)	Temp. (^{o}C)		Rainfall (mm)
	Max.	Min.		Max.	Min.	
October	34.0	19.0	0.0	33.0	16.0	13.0
November	27.0	9.0	0.0	25.0	10.0	0.0
December	21.0	3.0	0.0	22.0	5.0	0.0
January	17.0	3.0	2.5	16.0	5.0	9.2
February	21.0	7.0	29.0	22.0	8.0	1.1
March	28.0	11.0	5.5	30.0	15.0	2.2
April	34.0	16.0	11.5	37.0	19.0	0.0

Source: Arid Zone Research Institute (PARC), D.I. Khan, Pakistan

Results and Discussion

Leaf area indices (56 and 112 days after sowing): Leaf area index is the ratio of area covered by plants (leaf area) to the ground area. The perusal of the data indicated significantly ($p<0.05$) higher leaf area index (0.16) at 56 days in plots receiving 100% of recommended nitrogen at sowing as compared to rest of the treatments during the first year study (Table 3). The second year study showed non-significant ($p>0.05$) variations however, data showed the same trend as noted in previous year. The higher LAI obtained in plots receiving full nitrogen dose at sowing may be due to vigorous growth on account of maximum availability of nutrient. Our results are in line with those of Oscar and Tollennar (2006) who reported increased LAI with higher nitrogen levels.

LAI at 112 days was significantly ($p<0.05$) affected by nitrogen time of application during both the years of study (Table 4). During the year 2009-10, maximum LAI (3.02) was obtained in plots receiving 25% of recommended nitrogen at sowing and 75% after cut. Plots receiving 75% of recommended nitrogen applied at sowing + 25% after cut and 50% recommended nitrogen applied at sowing + 50% after cut also produced statistically at par LAI (2.91 and 2.89), respectively. Control plots recorded minimum LAI (1.84). The trend of producing higher LAI with increased amount of nitrogen after cut was similar during the year 2010-11. It may be due to the optimum amount of nitrogen available for regeneration of tissues through increased cells expansion and elongation. The reverse was true for plots receiving no nitrogen. These results are in conformity with those of Amanullah *et al*., (2007) who recorded maximum LAI in plots to which N was applied in five splits with greater proportion applied at later stages. Bavec *et al*., (2007) also concluded that higher nitrogen rates for first and second top dressing increased LAI in both stages compared without dressing treatments.

Table 3. Leaf area index (56 DAS) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	0.12 b	0.11 NS
100% at sowing + 0% after cut	0.16 a	0.16
75% at sowing + 25% after cut	0.12 b	0.14
50% at sowing + 50% after cut	0.13 b	0.14
25% at sowing + 75% after cut	0.13 b	0.14
$LSD_{0.05}$	**0.015**	-

Table 4. Leaf area index (112 DAS) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	1.84 c	1.34 c
100% at sowing + 0% after cut	2.54 b	2.34 b
75% at sowing + 25% after cut	2.91 a	2.49 b
50% at sowing + 50% after cut	2.89 a	2.98 a
25% at sowing + 75% after cut	3.02 a	3.04 a
$LSD_{0.05}$	**0.238**	**0.206**

Table 5. Leaf area duration (56 DAS) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	0.99 b	0.94 NS
100% at sowing + 0% after cut	1.27 a	1.31
75% at sowing + 25% after cut	1.02 b	1.16
50% at sowing + 50% after cut	1.02 b	1.18
25% at sowing + 75% after cut	1.06 b	1.14
$LSD_{0.05}$	**0.182**	-

Table 6. Leaf area duration (112 DAS) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	29.5 c	21.5 c
100% at sowing + 0% after cut	40.6 b	37.5 b
75% at sowing + 25% after cut	46.5 a	39.9 b
50% at sowing + 50% after cut	46.2 a	47.7 a
25% at sowing + 75% after cut	48.3 a	48.7 a
$LSD_{0.05}$	**3.801**	**3.282**

Leaf area duration (56 and 112 days after sowing): Leaf area duration at 56 days was significantly ($p<0.05$) affected by time of nitrogen application during the first year while the second year resulted in non-significant variation (Table 5). During the year 2009-10, significantly higher LAD (1.27) was recorded in treatment receiving 100% recommended nitrogen at sowing. The second year data although showed non-significant ($p>0.05$) effect yet the trend was similar. As LAD is directly related to LAI so the higher LAD obtained with 100% recommended N at sowing was due to higher LAI recorded in this treatment and vice-versa.

LAD at 112 days was significantly ($p<0.05$) affected by nitrogen application time during both the years (Table 6). In 2009-10, plots receiving 25% recommended nitrogen applied at sowing + 75% after cut recorded the maximum LAD (48.3), however, treatments with 75 % recommended nitrogen at sowing + 25% after cut and 50% at sowing + 50% after cut recorded statistically at par LAD (46.5 and 46.2), respectively. The minimum LAD (29.5) was recorded in control. The second year results showed almost similar trend with maximum LAD in plots receiving greater amount of nitrogen after cut. It was probably due to greater magnitude of leaf area that persisted in the plots due to luxuriant growth on account of higher available nitrogen.

Crop growth rate ($g\ m^{-2}\ day^{-1}$): Growth parameters are very important to assess the development of plants. Weight increases are often determined by harvesting the entire plant or part of interest and weighing it rapidly, before too much water evaporates from it. Because of problems arising from variable water contents, many people, particularly those in crop productivity, prefer to use increase in dry weight of a plant or plant parts as a measure of its growth. Crop growth rate (CGR) was significantly ($p<0.05$) affected by time of nitrogen application during both the years of experimentation (Table 7). During the year 2009-10, the maximum CGR (13.48) was recorded in treatment receiving 25% of the recommended nitrogen at sowing + 75% after cut. Treatments with 50% recommended nitrogen at sowing + 50% after cut and 75% at sowing + 25% after cut also recorded statistically at par CGR of 12.62 and 11.79, respectively. The minimum CGR was, however, recorded in control treatment. The data exhibited similar trend of increased CGR value obtained with increase in the proportion of nitrogen applied after cut during the year 2010-11. The higher CGR recorded in plots receiving more nitrogen after cut was attributed to availability of sufficient nitrogen which subsequently enhanced photosynthetic activity and vice-versa. Our results are supported by Valadabadi & Farahani (2010) who found that application of nitrogenous fertilizer increased physiological growth indices of crops.

Plant height at maturity (cm): Plant height was significantly ($p<0.05$) affected by different timing of nitrogen application during both years of experimentation (Table 8). During 2009-10, maximum plant height (114.1 cm) was recorded in plots receiving 75% of recommended nitrogen applied at sowing and 25% after cut. However, plots having 100% of recommended nitrogen applied at sowing + 0% after cut and 25% of recommended nitrogen applied at sowing + 75% after cut also attained statistically at par plant height (111.8 and 108.5 cm), respectively. Control plots had short statured plants (77.0 cm). During the year 2010-11, plots with 50% of recommended nitrogen at sowing + 50% after cut produced the tallest plants of 114.7 cm. Statistically at par plant height (112.8 and 112.3 cm) was, however, attained by treatments receiving 75% of the recommended nitrogen applied at sowing + 25% after cut and 25% of the recommended nitrogen applied at sowing + 75% after cut, respectively. The control treatment produced short statured plants of 77.2 cm height. The reason of taller plants produced in nitrogen applied plots was probably due to the positive impact of the nutrient on their growth and vice-versa.

Table 7. Crop growth rate (g m^{-2} day^{-1}) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	5.03 c	4.91 d
100% at sowing + 0% after cut	10.57 b	8.44 c
75% at sowing + 25% after cut	11.79 ab	9.72 b
50% at sowing + 50% after cut	12.62 ab	10.53 a
25% at sowing + 75% after cut	13.48 a	10.63 a
$LSD_{0.05}$	**2.161**	**0.608**

Table 8. Plant height at maturity (cm) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	77.0 c	77.2 c
100% at sowing + 0% after cut	111.8 ab	110.5 b
75% at sowing + 25% after cut	114.1 a	112.8 ab
50% at sowing + 50% after cut	107.5 b	114.7 a
25% at sowing + 75% after cut	108.5 ab	112.3 ab
$LSD_{0.05}$	**6.411**	**3.864**

Table 9. No. of productive tillers (m^{-2}) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	090.25 c	091.2 d
100% at sowing + 0% after cut	220.5 b	224.8 c
75% at sowing + 25% after cut	248.0 ab	246.5 b
50% at sowing + 50% after cut	249.3 ab	256.8 ab
25% at sowing + 75% after cut	263.5 a	268.8 a
$LSD_{0.05}$	**38.37**	**12.42**

Table 10. Number of grains ($spike^{-1}$) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	38.3 b	36.9 d
100% at sowing + 0% after cut	51.0 a	47.3 c
75% at sowing + 25% after cut	53.0 a	52.1 b
50% at sowing + 50% after cut	52.2 a	57.5 a
25% at sowing + 75% after cut	55.3 a	56.8 a
$LSD_{0.05}$	**5.811**	**2.381**

Number of productive tillers (m^{-2}): Number of productive tillers showed statistically significant ($p<0.05$) variations during both the years of research (Table 9). During the year 2009-10, maximum number of productive tillers (263.5) was produced in treatment receiving 25% of the recommended nitrogen applied at sowing + 75% after cut. Plots with 50% of the recommended nitrogen at sowing + 50% after cut and 75% of the recommended nitrogen applied at sowing + 25% after cut, however, showed in statistically at par number of productive tillers (249.3 and 248.0 m^{-2}), respectively. It was followed by treatment receiving 100% of the recommended nitrogen applied at sowing + 0% after cut that produced 220.5 number of productive tillers. Minimum number of productive tillers (90.2) was noted in control treatment. Similar trend of producing productive tillers per unit area was observed during 2010-11. The reason of increased number of productive tillers in plots receiving split application of nitrogen may be due to sufficient availability of nitrogen during tillering stage. On the contrary, plots with no nitrogen or received all the nitrogen at sowing resulted in less number of tillers due to less availability of the nutrient. Bulk nitrogen application at sowing may have resulted in leaching or volatilization of the nutrient that subsequently resulted in significantly lower number of productive tillers. Njuguna *et al*., (2010) concluded that nitrogen application increased the number of fertile tillers (m^{-2}) and grain yield. Abedi *et al*., (2011) showed that no N application decreased the number of productive tillers (m^{-2}).

Number of grains $spike^{-1}$: The data showed statistically significant ($p<0.05$) difference regarding number of grains ($spike^{-1}$) in dual-purpose wheat (Table 10). During the year 2009-10, it was noted that control treatment produced the minimum (38.3) number of grains ($spike^{-1}$) while rest of the treatments produced the maximum and statistically at par number of grains ($spike^{-1}$). During the year 2010-11, maximum (57.5) number of grains ($spike^{-1}$) was noted in treatment receiving 50% of the recommended nitrogen at sowing + 50% after cut. Treatment with 25% of the recommended nitrogen applied at sowing + 75% after cut also showed statistically at par (56.8) number of grains ($spike^{-1}$). It was followed by treatment having 75% nitrogen applied at sowing + 25% after cut. Control treatment produced minimum (36.9) number of grains ($spike^{-1}$). Overall the number of grains ($spike^{-1}$) increased linearly with increase in the amount of nitrogen applied after cut. The reason of increased number of grains produced in plots receiving major portion of the nutrient after cut may be attributed to the positive role of nitrogen in cells expansion, enlargement and over and above the grain filling. Martre *et al.*, (2003) reported decreased grain numbers under nitrogen deficiency conditions.

Grain yield (kg ha^{-1}): Grain yield was significantly ($p<0.05$) affected by different timings of nitrogen application during both the years of research (Table 11). During the year 2009-10, maximum grain yield (4331 kg ha^{-1}) was recorded in plots with 25 % of the recommended nitrogen at sowing + 75% after cut. It was, however, not statistically different (4196 and 4009 kg ha^{-1}) from plots receiving 50% of the recommended nitrogen applied at sowing + 50% after cut and 75% of the recommended nitrogen applied at sowing + 25% after cut, respectively. The minimum grain yield (873 kg ha^{-1}) was recorded in control treatment. The trend was almost similar with respect to grain yield during the second year study. The data during both the years manifested that grain yield increased progressively with split application of nitrogen being maximum in treatment receiving larger quantity of nitrogen applied after cut. It may be due to efficient utilization and arresting volatilization or leaching down of nitrogen. The reverse was true for either no nitrogen applied plots or those applied in bulk at sowing. The results regarding enhanced grain yield due to split application of nitrogen are ascertained by Abedi *et al*., (2011) who demonstrated that the amount of N fertilization before wheat planting was completely unnecessary and was likely to move beyond the root zone, particularly under irrigated conditions. Similar results were also reported by other researches (López -Bellido *et al*., 2005; Chen *et al*., 2006; Cui *et al*., 2010). Woolfolk *et al*., (2002) who concluded that nitrogen application near flowering is effective to increase post-flowering nitrogen uptake, grain yield, and grain protein content. Wuest & Cassman (1992) found that pre-plant nitrogen application may lead to immobilization before plant uptake, greatly affecting nitrogen use efficiency and hence the yield.

Fresh forage yield (kg ha^{-1}): The data regarding fresh forage yield under different timings of nitrogen application are given in Table 12. It is evident from the data that fresh forage yield was significantly ($p<0.05$) affected during both the years of experimentation. During the first year study, maximum fresh forage yield (2135 kg ha^{-1}) was produced by treatment receiving 75% of the recommended nitrogen applied at sowing + 25% after cut. Statistically at par fresh forage yield (2120 and 2059 kg ha^{-1}) was obtained in plots supplied with 50% recommended nitrogen at sowing + 50% after cut and 100% recommended nitrogen applied at sowing, respectively. It was followed by treatment (1832 kg ha^{-1}) with split application of nitrogen i.e., 25% at sowing + 75% after cut. Control treatment produced the minimum fresh forage yield (596 kg ha^{-1}). Almost similar trend was noticed during the second year study showing maximum fresh forage yield in plots receiving full or major portion of the recommended nitrogen at sowing. The production of maximum fresh forage yield may be attributed to maximum availability of nitrogen during early growth stages that resulted in increased vegetative growth and *vice versa*.

Table 11. Grain yield (kg ha^{-1}) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	873.6 c	1051 d
100% at sowing + 0% after cut	3751 b	3447 c
75% at sowing + 25% after cut	4009 ab	3929 b
50% at sowing + 50% after cut	4196 a	4062 ab
25% at sowing + 75% after cut	4331 a	4150 a
$LSD_{0.05}$	**404.2**	**196.5**

Table 12. Fresh forage yield (kg ha^{-1}) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	2009-10	2010-11
0% at sowing + 0% after cut	596 c	598 d
100% at sowing + 0% after cut	2059 ab	2545 a
75% at sowing + 25% after cut	2135 a	2395 ab
50% at sowing + 50% after cut	2120 a	2259 b
25% at sowing + 75% after cut	1832 b	1930 c
$LSD_{0.05}$	**271.7**	**171.3**

Dry forage yield (kg ha^{-1}): The data regarding dry forage yield was significantly ($p<0.05$) affected by different timing of nitrogen application during both the years (Table 13). Treatment that received 75% of the recommended nitrogen at sowing + 25% after cut produced the maximum dry forage yield (372 kg ha^{-1}) during the year 2009-10. Statistically similar dry forage yield (337 kg ha^{-1}) was, however, obtained in the treatment receiving 50% of the recommended nitrogen at sowing + 50% after cut. It was followed (312 kg ha^{-1}) by treatment that received 100% of the recommended nitrogen at sowing. Control plots produced minimum dry forage yield (170 kg ha^{-1}). During the year 2010-11, maximum and statistically at par dry forage production (349 and 333 kg ha^{-1}) was noted in treatment receiving 100% of recommended nitrogen at sowing and 50% of recommended nitrogen applied at sowing + 50% after cut, respectively. It was followed (320 kg ha^{-1}) by treatment with 75% of recommended nitrogen at sowing + 25% after cut. The possible reason of maximum dry forage yield obtained in treatments receiving maximum amount of nitrogen applied at sowing may be due to adequate availability of nutrient which triggered the physiological growth processes and produced more foliage. Khalil *et al*., (2011) also found that maximum nitrogen produced maximum forage dry matter and biological yield.

Table 13. Dry forage yield (kg ha^{-1}) and grain protein content (%) as affected by time of N-application in dual-purpose wheat during 2009-2010 and 2010-2011.

Time of application of nitrogen	Dry forage yield (kg ha^{-1})		Grain protein (%)	
	2009-10	2010-11	2009-10	2010-11
0% at sowing + 0% after cut	170.d	167 d	9.41	10.06
100% at sowing + 0% after cut	312 b	349 a	10.94	11.16
75% at sowing + 25% after cut	372 a	320 b	11.16	10.94
50% at sowing + 50% after cut	337 ab	333 ab	10.94	11.60
25% at sowing + 75% after cut	228 c	243 c	11.81	12.03
$LSD_{0.05}$	**51.29**	**24.30**	**-**	**-**

Grain protein content (%): Grain protein is an important factor that influences the milling and baking quality of wheat (Woolfolk *et al*., 2002), and N is the major nutrient that influences grain protein content (Bly & Woodward, 2003). The data regarding grain protein content (Table 13) showed that split application of nitrogen increased grain protein content over sole or no application of nitrogen during both the years of experimentation. Grain protein content increased with increase in the quantity of nitrogen applied after cut. Maximum grain protein content (11.81) was found in plots that received 25% of the recommended nitrogen at sowing and 75% after cut while minimum (9.41) was obtained in control plots during the first year trial. Similar trend was noted during the second year study. The possible reason of higher grain protein content in the said treatment may be due to application of major portion of nitrogen after cutting forage that resulted in translocation of more nitrogen to grains and ultimately increasing the grain protein content. Our results are in line with those of Farrer *et al*., (2006) who reported that the time and rate of N application had profound effects on protein quality of the grains and forage and hence on dual purpose wheat production.

Benefit cost ratio (BCR): The data regarding benefit cost ratio (Tables 14 and 15) showed that higher net income and BCR was obtained with split application of nitrogen fertilizer. During the first year study, maximum BCR (2.33) were obtained when the recommended nitrogen fertilizer was applied in two equal halves as pre-cut and after-cut, respectively while minimum BCR (0.56) was obtained when no nitrogen was applied. The BCR increased with increase in quantity of nitrogen applied after cut. The second year results showed almost similar response with maximum BCR (1.99) in treatment receiving 25% of the recommended nitrogen before cut and 75% after cut. It may be attributed to increased grain yield that fetched more prices. Our results are in conformity with the findings of Wood *et al*., (2003) who obtained the greatest benefits where the total amount of applied nitrogen was similar to the standard, but was applied variably rather than uniformly along the strips. Koch *et al*., (2004) found variable N application to be economically more feasible than conventional uniform N application.

Table 14. Benefit cost ratio (Rs.) as affected by time of N-application in dual-purpose wheat during the year 2009-10.

Time of application of nitrogen	Cost			Income				Net income	BCR
	Fixed	Variable	Total	Grains	Fodder	Straw	Total		
0% after sowing + 0% after cut	43324	1800	45124	19752	2980	2622	25354	-19770	0.56
100% after sowing + 0% after cut	48832	1800	50632	84772	10295	11253	106320	55689	2.10
75% after sowing + 25% after cut	48832	1800	50632	90603	10675	12027	113305	62673	2.24
50% after sowing + 50% after cut	48832	1800	50632	94829	10600	12588	118017	67386	2.33
25% after sowing + 75% after cut	48832	1800	50632	95620	9160	12693	117473	66842	2.32

Rate of wheat seed = Rs.22.60 per kg, Rate of wheat fodder = Rs. 5.00 per kg, Cutting of wheat fodder = Rs. 1800.00 per hectare, Rate of wheat straw = Rs. 300.00 per 100 kg grains, Rate of urea = Rs. 850 per bag

Table 15. Benefit cost ratio (Rs.) as affected by time of N-application in dual-purpose wheat during the year 2010-11.

Time of application of nitrogen	Cost			Income				Net income	BCR
	Fixed	Variable	Total	Grains	Fodder	Straw	Total		
0% after sowing + 0% after cut	49402	1800	51202	23122	2990	3678	29790	-21412	0.58
100% after sowing + 0% after cut	56206	1800	58006	75834	12725	12064	100623	42618	1.73
75% after sowing + 25% after cut	56206	1800	58006	86438	11975	13751	112164	54159	1.93
50% after sowing + 50% after cut	56206	1800	58006	89364	11295	14217	114876	56870	1.98
25% after sowing + 75% after cut	56206	1800	58006	91300	9650	14525	115475	57469	1.99

Rate of wheat seed = Rs.22.0 0 per kg, Rate of wheat fodder = Rs. 5.00 per kg, Rate of wheat straw = Rs. 350.00 per 100 kg grains, Cutting of wheat fodder = Rs. 1800.00 per hectare, Rate of urea = Rs. 1050 per bag

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